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UNITED STATES DEPARTMENT OF AGRICULTURE

TECHNOLOGICAL TRENDS

IN RELATION TO

AGRICULTURE

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I. AGRICULTURE

By S. H. McCrory, R. F. Hendrickson and Committee [1]

Introduction

Few industries are influenced by as many and varied technologies as agriculture. These technologies are, of course, unequal in influence. Similarly, the numerous branches and types of agriculture represented in this country are very uneven in their responsiveness to technologies.

To forecast scientific discovery, mechanical invention, or the rise of new methods is a hazardous undertaking. To weigh their probable influence is infinitely more hazardous. It is evident that the effects of many technological developments long known and widely applied in farming have escaped accurate measurement.

All this has been recognized in this effort to indicate future trends in technology as they may affect agriculture. Because of the large variety of technologies which bear on agriculture, specialists in fields which have contributed greatly to technological change in agriculture—fields in which there is reasonable expectation for further advance—have been invited to indicate avenues of promise. They have been asked to relate these to past and, especially, to recently erected milestones of discovery so as to assist in throwing light on economic and social implications of developments ahead.

Men are not possessed of equal amounts of hope and caution. The sections of this chapter which follow reflect this factor of human variability. Some contributors may prove to have been too optimistic with regard to both future developments and their implications; others are doubtless cautious to an extent that will be handicapping to persons who are anxious to anticipate future technologies with a view to preparing for them.

It should not be inferred that technological change affecting agriculture is limited to fields dealt with here. Such a view would be as unwarranted as opinions that new discoveries, inventions, and techniques will come only in the formalized areas of investigation—or only from those who are seeking them.

I. TECHNOLOGY: ITS ADVANCE AND IMPLICATIONS

The productivity of the average worker in agriculture has been stepped up greatly in the past 100 years and this trend promises to continue. The rate of the increase has been almost steadily rising. If this continues to be the trend numerous adjustments will be necessary in the future. And these adjustments will mean social and economic change as surely as the past 100 years have brought change affecting in some way every person engaged in agriculture.

Contributions making possible the increase in productivity have come from many sources and not alone, as is often supposed, from the invention, improvement, and use of machinery and power. Major contributions have come through the introduction, adaptation, and improvement of plants and livestock; the increased ability to meet the challenges of insects, pests, and diseases; increase in knowledge relating to the use and replenishment of soils; and improvement in managerial and marketing techniques.

None of these sources has run dry. Few technologies available to agriculture have been utilized fully. Maximum efficiency in farm production has not been reached and is not in sight. It could not be reached without social cost; it cannot be stopped without social cost.

The March of Change

Twenty-five years after the signing of the Declaration of Independence farmers here and abroad were still employing largely the techniques of 3,000 years before. Plows were wooden, crude. In many areas hand tools were favored over plows in preparing soils for seeding. Cotton and corn were planted by dropping seed and covering it with a hoe—much as surburban gardeners of today plant radishes, endive, or sweet corn. Small grains were sown by hand. Cultivation and harvest were performed largely with hand methods.

The cotton gin, invented soon after the Revolutionary War, was one of the earliest of a long series of inventions that changed greatly the character of American farm production. Authorities are not in

[1] This chapter was prepared under the direction of S. H. McCrory, chairman, and Roy F. Hendrickson, secretary, of the committee on technology of the U. S. Department of Agriculture. Mr. McCrory is the Chief of the Bureau of Agricultural Engineering. Mr. Hendrickson is Director of Economic Information of the Bureau of Agricultural Economics. Other members of the committee are: H. T. Herrick, Bureau of Chemistry and Soils; Russell S. Kifer, Bureau of Agricultural Economics; O. V. Wells, Agricultural Adjustment Administration; S. C. Salmon, Bureau of Plant Industry; Earl O. Whittier, Bureau of Dairy Industry; and Paul Howe, Bureau of Animal Industry. The committee was assisted by Roman L. Horne, Caroline B. Sherman, A. B. Genung, and other members of the Department's staff whose contributions are noted in the various sections of the chapter. The introduction and the section on Technology: Its Advance and Implications were written by Mr. Hendrickson.

agreement as to the exact date the grain cradle was introduced. However, there is sufficient available information to fix the date sometime between 1760 and 1800. The iron plow came into general use about 1820 to 1830. The hay rake and the first crude threshing machine came into use soon after. An abundance of land was available for crops and livestock. Export markets opened, especially for grain.

The three decades, 1830 to 1860, constituted an outstanding period in the development of farm machinery. During the Civil War, with manpower on farms reduced and the demand for food increased, there were developed or greatly improved the mowing machine, the steam tractor, the grain separator, and the reaper. The war removed a million men from northern farms alone, while needs for farm products increased—incentives to change quite different from those which now exist.

The stream of mechanical improvements continued to flow. The invention of the internal-combustion engine opened the way to development of the modern tractor. This in turn opened the way to development of more implements. Today farmers can obtain from merchants in nearly every community, or by mail order, a large and growing variety of mechanical aids. Meanwhile, plants have been adapted to meet tests of higher efficiency from the standpoint of increased yields, better quality, and resistance to disease, and to meet a wide variety of growing conditions. Specific qualities in livestock have been stressed in breeding, particularly more efficient feed utilization.

Areas of land that resisted profitable cultivation before have been utilized since the arrival of the tractor. The introduction and adaptation of plants have helped to make this possible. The Corn Belt was moved northward and westward by the corn breeder. The introduction of Russian strains of wheat pushed production westward into dry-farming areas. The development of rust-resistant grains contributed to increasing yields in many wheat-producing areas.

Numerous diseases affecting plants, trees, and animals have been brought under control or weapons have been provided for fighting them effectively. It is said that every trace of hoof-and-mouth disease, which brought heavy losses and costly preventative measures on several occasions, has been stamped out of the United States, even out of research laboratories.

Changes Affecting Rural Living

Technological development has brought and will continue to bring other primary and derivative influences affecting rural conditions of living and not alone in the fields of crop and livestock production. The automobile, the radio, the telephone, the daily and weekly newspaper have increased the means of communication, bringing farmers, in terms of time and distance, closer to each other and to centers of population, education, and entertainment. Motion pictures have affected rural habits and customs. Although they elude adequate measure, their effects on the fashions, speech, and moral attitudes of rural people are many and evident. Rural mail delivery and improved roads have become available to very large numbers of country people. The opening of avenues of communication has meant the breaking down of many provincial barriers.

But like technologies primarily influencing efficiency in production, these streams of influences have not spread out evenly over the countryside. Low incomes appear to be the most important limiting factor in accounting for the large numbers of farm families without telephones, automobiles, radios, electricity, and household labor-saving equipment. Many farms relatively well equipped with modern production tools and techniques are without running water, bathrooms, and electric lights, and other comforts and conveniences. It is frequently said that overemphasis has been placed on production efficiency by farmers generally; that they have passed on their gains too readily as a result of intense competition; and that they have tended to overcapitalize their land, thus limiting their ability to acquire conveniences contributing to raising living standards.

Technology Often Blamed

Technology is often charged with this responsibility. The difficulty is not with technology; it is with the failure of the economic and social system to make needed readjustments.

There are extreme variations in planes of rural living measurable in terms of creature comforts. Wide variations occur in rural housing and the use of household conveniences. Educational opportunities for rural people are unequal in the extreme. Community services vary widely, not alone between regions, but between communities. Resources that form the foundation of livelihood vary widely, of course. These variations point to the necessity of avoiding extremes in generalizing regarding farms and farmers. In considering technology and the farmer, sight should not be lost of the fact that many forces beyond the immediate control of farmers as individuals operate to encourage and discourage utilization of many branches of science and invention.

Although electricity has been very generally used in cities and villages for many years, only about 12 percent of American farms are being served from a central power plant. In Holland 100 percent of the farms are electrified, while in Germany about 90 percent have electricity. It is true that conditions are

not similar here and in those nations; the size of farm units and the character of the agriculture are among the noteworthy differences. Electrification of farms, with public support through creation of the Rural Electrification Administration, is proceeding more rapidly than before. Electrification means the addition of devices and services, many of which contribute directly to increase in productive efficiency of farm workers. The relatively great distance between American farms has been a major handicap to electrification.

Increase in Productivity

In 1787, the year the Constitution was framed, the surplus food produced by 19 farmers went to feed one city person. In recent average years 19 people on farms have produced enough food for 56 nonfarm people, plus 10 living abroad.

Productivity per farm worker increased steadily, and at very nearly the same rate in agriculture as in industry during the 75 years after 1850. Between 1910 and 1930, output per worker increased 39 percent in manufacturing and 41 percent in agriculture.

The Institute of Economics of the Brookings Institution [2] developed an index of labor efficiency in agricultural production, based in part on census reports. Agricultural production per male employed in agriculture during the 5 years centering on 1899 was represented by the figure 100. A decade later the index stood at 99.2, two decades later at 112.1, and during the 5-year period centering on 1929 at 143.1. The index of agricultural production per year of labor for the same periods, it reported as follows: 1897–1901, 100; 1907–11, 97.2; 1917–21, 107.6; 1927–31, 132.9.

The decade of the twenties witnessed a striking increase in farm efficiency in terms of productivity. From 1922 to 1926, production increased 27 percent while crop acreage remained little changed and the number of workers in agriculture decreased.

Studies by the Bureau of Agricultural Economics of estimated amounts of man labor used by growers for producing an acre of 100 bushels of wheat, of 100 bushels of corn, and 500-pound gross-weight bales of

[2] America's Capacity to Produce, 1934, p. 38 (published by the Brookings Institution, Washington, D. C.)

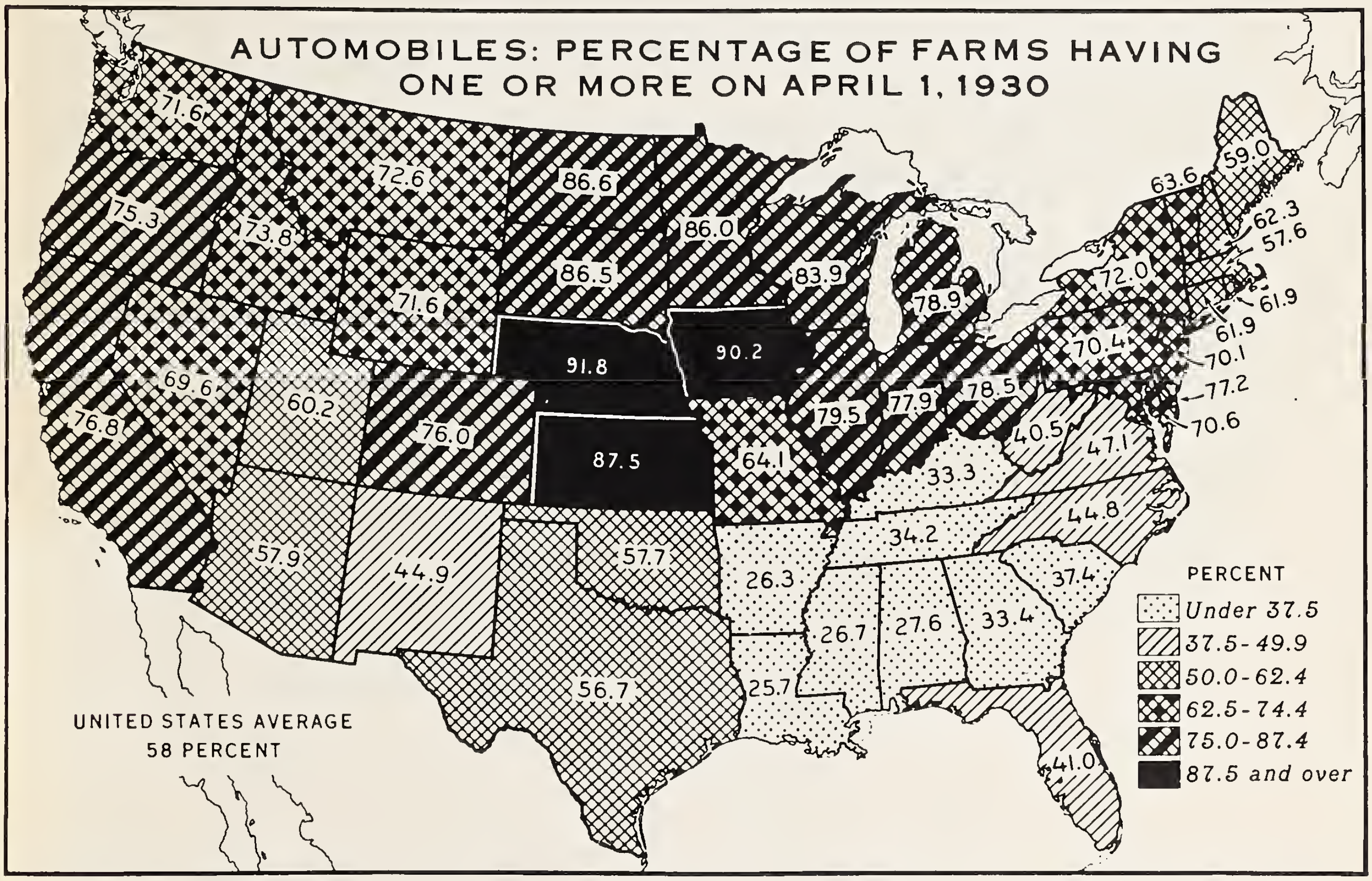

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FIGURE 5. As automobiles are kept both for use in farm business and for pleasure, a high percentage of the farms of the country are so equipped. Only in the Southeastern States and in Arizona do the percentages run less than 50, while in the Northern States, from 60 to 85 percent of the farms reported automobiles.

cotton for designated periods (5-year averages) reveal striking changes over a half century (table 10).

Between 1930 and 1935, agricultural production declined more than 10 percent, owing principally to unfavorable weather. Meanwhile, because of urban unemployment conditions, nearly 2,000,000 people were living on farms on January 1, 1935, who were not living on farms 5 years before, and perhaps 2,000,000 farm youth remained on farms who would have migrated to cities if jobs had been available. This had the effect of reducing per capita productivity on farms. Productivity per worker probably declined 20 percent between 1929–30 and 1934–35, with about one-half of this decline due to droughts.

An important factor in increasing per worker productivity, especially during the twenties, was that as mechanical power increased, land formerly required for producing feed for horses and mules was released for the production of commodities offered for sale. The loss of about 9,000,000 horses and mules on farms between 1918 and 1932—and probably a million more in cities—is credited with releasing more than 30,000,000 acres each of crop land and pastures.

In 1920 the production of butterfat per cow in herds owned by members of 452 dairy-herd-improvement associations averaged 247 pounds annually. By 1928 the average had increased to 284 pounds; by 1930 to 302 pounds, and by 1932 to 310 pounds. In the 5 years preceding the depression the number of dairy cows in the Nation was about 5 percent greater than 10 years before. The production of milk was 25 percent greater while it is estimated the consumption of feed did not increase over 15 percent.

Fewer Farms—Fewer Farmers

Farmers do not and cannot apply at equal rates the products of science and invention. Out of this fact arises one of the most significant impacts of technological change in agriculture.

In some types of agriculture per capita productivity has increased much more slowly than in others. The increase in efficiency has been most striking in the production of grain and hay crops. Cotton, fruit, and tobacco production have been given less mechanical assistance than grain and hay. Most cotton and fruit is still picked by hand. Science has aided the

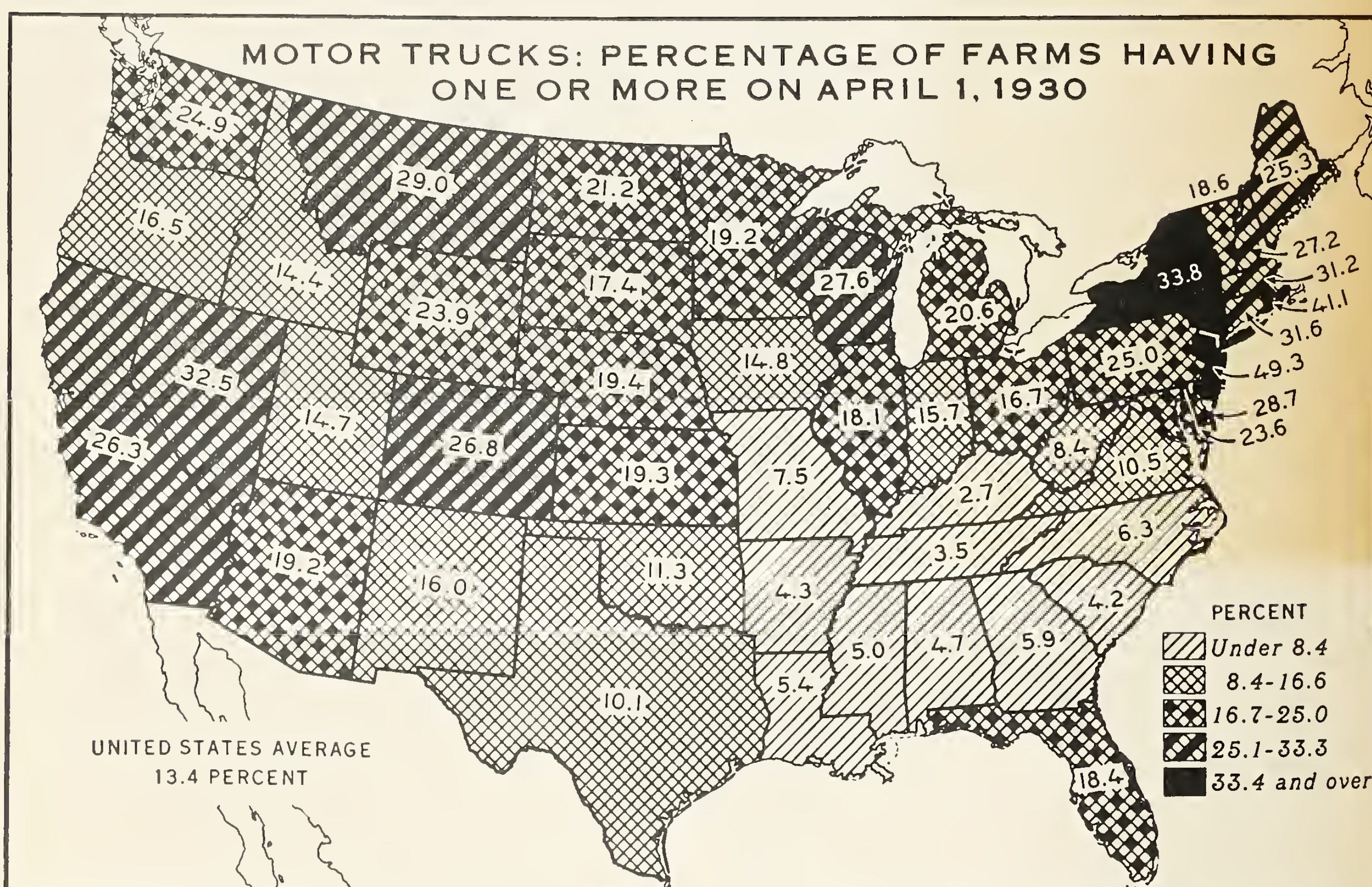

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FIGURE 6. The distribution of motor trucks on farms is somewhat less concentrated than is the distribution of tractors on farms. However, probably above 85 percent of all motor trucks are located in the eastern half of the United States, with the heaviest concentration in the general vicinity of New York City. Trucks are more plentiful in the South and West than are tractors.

TABLE 10.—*Estimated amounts of man labor used to produce an acre of 100 bushels of wheat, of 100 bushels of corn, and 500-pound gross weight bales of cotton for designated periods*

	Yearly average for—		
	1878–82	1898–1902	1928–32
Wheat:			
Man labor per acre:			
Prior to harvest.........hours..	6	5	3
Harvest.................do....	11	7	4
Total, hours................	17	12	7
Acreage harvested.......acres..	36, 160, 000	49, 929, 000	58, 722, 000
Production..........bushels..	476, 061, 000	694, 576, 000	844, 640, 000
Yield per acre..........do....	13. 2	13. 9	14. 4
Man labor per 100 bushels...hours..	129	86	49
Corn:			
Man labor per acre:			
Prior to harvest.........hours..	28	22	14
Harvest.................do....	18	16	12
Total, hours................	46	38	26
Acreage harvested.......acres..	62, 857, 000	94, 319, 000	102, 393, 000
Production..........bushels..	1, 609, 966, 000	2, 441, 882, 000	2, 557, 071, 000
Yield per acre..........do....	25. 6	25. 9	25. 0
Man lahor used per 100 hushels hours..	180	147	104
Cotton:			
Man lahor per acre:			
Prior to harvest.........hours..	67	62	48
Harvest.................do....	52	51	37
Total, hours................	119	113	85
Acreage harvested.......acres..	15, 125, 000	25, 675, 000	40, 535, 000
Production (500-pound gross-weight bales)...............	5, 917, 000	10, 177, 000	14, 656, 000
Yield per acre (pounds gross lint).....................	196	198	181
Man lahor per bale........hours..	304	285	235

production of all of these, particularly in fighting off enemies, such as disease and pests.

For topographical reasons many farms are not suited to effective use of tractors. They may be hilly or poorly drained. A barrier to their use which is far more general is the size of the farming unit or the character of the farming enterprise. Tractors and machines mean a considerable investment. The investment cannot be justified in terms of lower production costs and higher net income if equipment is idle beyond certain time limits. A four-row corn planter is not economically justified on a farm that has only 10 to 20 acres of corn. Thus there has been added to "man-sized farm" and "family-sized farm" the term "tractor-sized farm."

Generally, technological trends in agriculture have been in the direction of larger and larger farm units. Recently in the case of machinery an influence tending to modify this trend has been emphasis on development of smaller units. Many of the smaller units, as in the case of tractors and combines, are high in efficiency relative to larger units.

Many techniques do not require larger farm units and the emphasis on larger units varies a great deal between branches of agriculture and the regions where these are important. Larger-scale operations in some lines, particularly where extensive farming is the most efficient practice, are likely to increase, while at the same time other farms, offering opportunity for intensive land use, may tend to become smaller.

The adjustments toward larger units is not readily made because of limitations on the ability of most farmers to acquire more land and the problem of an alternative opportunity to make a livelihood by those who would sell or lease their farms to others.

Larger units in many types of farming, particularly those which lend themselves to mechanization, tend to reduce production costs and increase net income. They make possible a greater division of labor with more specialization; they justify larger investments in machinery; they make possible purchases of supplies in larger quantities and reduce overhead costs much in the way larger factory units achieve certain economies that are impossible for smaller competitors. But, except for very rare cases incident to the production of specialties, the farm unit, no matter how large, cannot harvest the monopoly gains that in many cases grow out of consolidation of industrial units.

Large units do not escape the fact that the proportion of fixed costs is relatively much higher in agriculture than in industry. Production and prices of farm products are much less certain than production and prices of many, if not most, industrial products. The large farming enterprise is therefore subject to many risks—the vagaries of weather, pests, and diseases, even though technology has erected some effective defenses against these. The farming enterprise built around a family has shown an extraordinary capacity to weather these risks. The family will sacrifice living standards and will continue producing even when returns on its labor are reduced to very low levels.

Potential Farm Production

Thus potential production cannot be dealt with realistically in terms of achieving maximum efficiency quickly. The readjustment, involving as it would widespread reorganization in terms of larger units, could not be accomplished speedily even if that were desirable. The risks involved are of limited attractiveness to capital at the present time. With the existing limitation on alternative opportunities of employment for persons not engaged in agriculture, operating farm owners would not readily part with their holdings.

More persons now are engaged in agriculture than can be supported if a steady rise in rural living standards is to be achieved. Unless there is an increase in

the rate at which rural people are absorbed in industry, the number of persons to be supported by agriculture will continue to increase. Rural birth rates are characteristically higher than are the rates for any other major population group. Rural areas are now responsible for most of the Nation's net increase in population. Some decline in rural birth rates has been indicated in recent years and a trend toward a further decrease is probable, because the gradual spread of birth control is to be expected.

But larger farms and a smaller proportion of the Nation's population engaged in agriculture do not necessitate abandonment of the principle of family-sized farms, a traditional objective in American agriculture. Reorganization of family farms in terms of size and adjustments in practices has been going on steadily in response to technological and other factors for generations. This will continue. Many farms have decreased in size with gains in efficiency when the type of agriculture has changed reflecting some factor such as a new road to a city market or establishment of a canning factory that has made truck growing profitable where more extensive farming was practiced before. There have been and there will continue to be decreases also where there are opportunities for outside employment, often part-time. But where the opportunity for an increased income arises only out of commercial farm production the chief trend will be toward that size unit which promises lower costs—and this promise generally is identified with more land.

Production which is most highly efficient in terms of maximum income for labor and expense involved does not necessarily imply higher average per acre yields. The law of diminishing returns imposes a definite limitation on forcing output. It is a limiting factor which imposes a barrier of practicality to such spectacular feats as producing vast quantities of given products in trays, in greenhouses, or on small areas of land intensively fertilized. The possibility that these methods may prove increasingly practical is, however, by no means closed.

There are many individual estimates that application of maximum use of present available technologies in agriculture might mean an increase from 25 to 50 percent in output, somewhat irregularly distributed among commodities. They cannot be proved, but they

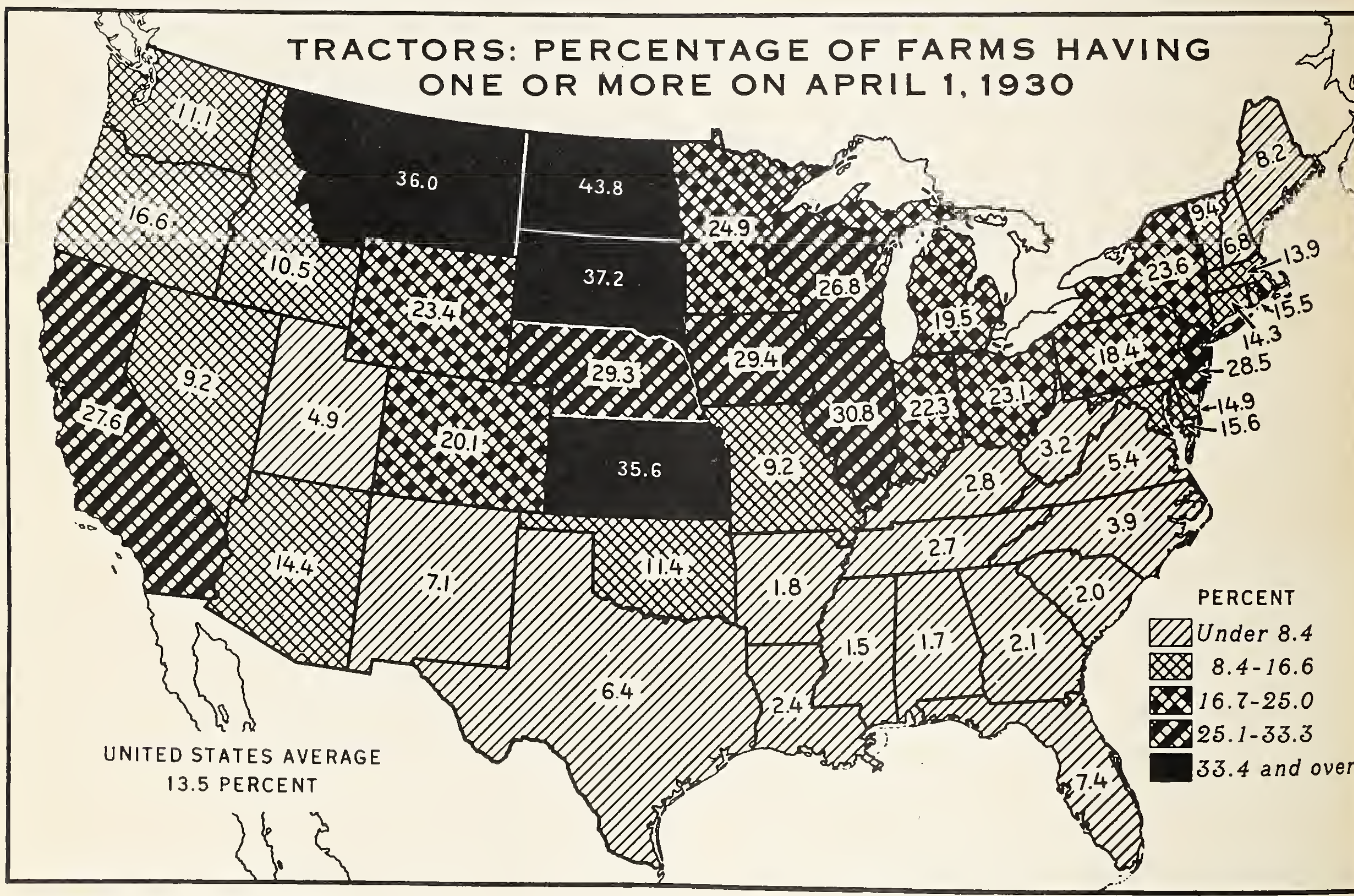

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FIGURE 7. If a north-south line were drawn across the Great Plains area dividing the country in half it would be seen that fully 90 percent of all tractors on farms are located in the eastern half of the United States. This concentration, centering around the Great Lakes, is due in part to differences in soil and topography, the greater density of population in the east and the type of agriculture practiced. Note the comparative absence of tractors on farms in the Cotton Belt and in the Western Mountain and range States.

have a sufficient basis of fact to deserve consideration.

Assuming that the present area devoted to agriculture were not reduced, this would mean, over a period of years with average weather, vast unsalable surpluses. For agriculture continues to stand face to face with the problem of an increasing potential capacity to produce out of proportion to its capacity to gain outlets for its products.

Markets for Farm Products

Foreign markets for farm products are not being reopened rapidly. Yet the Nation's farm plant continues to be on a scale capable of sending 12 to 25 percent of its output abroad in years of average crop yields.

Domestic requirements for farm products remain relatively inelastic. There is doubt whether consumption at present levels of consumers incomes would increase more than 10 percent even if it were possible to reduce prices of farm products 25 to 50 percent. Domestic consumption of farm products remained relatively stable during the years 1930 to 1933 while farm prices were extremely low. Since food habits are relatively inflexible, it is doubtful that any but the very poor would consume much more as a result of a substantial increase in consumer income. New industrial uses, while promising, do not at present offer definite outlets for large quantities of products beyond present utilization. This subject is discussed in a separate section later in this chapter.

In principle, gains in efficiency are largely passed on ultimately to consumers. In the case of gains in farm output they appear to be passed on at a rate which is rapid in relation to other industries which are not made up of so many units. In agriculture the factor of many competing units forestalls widespread group action in maintaining price levels.

If all farmers adopted improvements simultaneously, consumers would get most of the benefits quickly under the system of competition that applies to most farming enterprises. But there is a lag in their adoption. As a result farmers who first adopt methods contributing to efficiency gain while the others are following up at an uneven pace. Often these gains are not so great as might be supposed because those who lag are usually the least capable or insistent in defending their living standards.

Social cost would be reduced if the problem of readjusting to a change involving a major gain in efficiency could be solved by farmers, through concerted action. They might reduce their hours of labor or shift production to other lines, unaffected by the new technique, where consumption might be expanded.

Long hours of labor during busy seasons is a farm characteristic. On diversified farms work may be so arranged that the busy season continues around the year with few if any vacations for the farmer or the housewife.

For many other farmers profitable employment during more days of the year is necessary if income is to be increased sufficiently to make higher living standards possible. A promising field exists here for science and invention to create more opportunities of work to fit this need.

As in the case of hours of labor, there are limits to avenues of escape through shifting production. There are many commodities which are not produced in excess in terms of consumer needs, particularly of low-income consumers including many farmers. But farmers cannot produce irrespective of price in terms of exchange value without going bankrupt. Dependent as they are on incomes of consumers, they cannot produce without respect for consumer demand. Thus their interest in consumers of farm products is a reflection of their own place as consumers of industrial and other products. If these were available to them at increasingly lower prices, their concern with maintaining historic price levels for their products would receive less emphasis.

Marketing Techniques

Motortruck transportation of farm products has increased rapidly. It is likely this trend will continue. It has resulted in many changes in the comparative advantages of various producing areas. It is discussed more fully in the chapter on transportation.

Improvements in refrigeration have opened the way to improving the quality of products laid down in consuming centers and in reducing waste. This contribution to more efficiency in agriculture, discussed more fully later in this chapter, is only one of many which may be expected to contribute as much to improving utilization of products as to increasing requirements for them, with variations among commodities. The reduction of waste, whatever its immediate effects may be, can deserve only encouragement in terms of the general welfare.

Perhaps one of the most significant contributions to marketing has been the increase in use of grades and standards. Through these a common language for producers, middlemen, and consumers is being more firmly established. It encourages more emphasis on quality in production; and purchases by consumers on the basis of quality factors. The farmer is also being enabled better to adjust his plans to the markets through improved techniques in market news reporting. The Market News Service of the Bureau of Agricultural Economics distributes quotations on all principal farm products through newspapers, the mail, and radio stations. Farmers who once were unaware of

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significant price changes for days and weeks now can hear them over radios within a very short time after they have taken place.

Cooperation in Agriculture

Cooperative marketing and cooperative buying are gaining a place of increasing significance in agriculture. This reflects, to a considerable degree, advances in technology which have made them possible or necessary. It is probable that this trend will continue. It is probable that it will be extremely important in assisting the system of family farms to meet the challenge of new technologies.

Cooperative ownership of farm equipment such as threshers, wood-sawing rigs, sorghum sirup plants, creameries, cheese factories, grain elevators, and terracing machinery may be expanded. Investment in a machine may not be justified for a single farm but the machine may pay its way when used on several farms.

There has been a steady rise in the volume of business done by farmer consumer cooperatives, particularly in the purchase and distribution of production goods such as fertilizers, feeds, twine, gasoline, and oil. This trend is certain to continue.

There has been another relatively new development—cooperative farm-management associations. In these, farmers jointly employ one or more experts to check their operations and to maintain cost and production records. Measures of labor, feed, machinery, and other factors are developed and from these measures are developed programs for changing farm production plans. Individuals and firms are also offering similar services for a fee and many nonresident farm owners have placed their properties in the custody of these specialists.

An important factor in assisting agriculture to narrow the gap between the rise and use of a new technique has been the erection of institutions. The public, through the land grant colleges, the United States and State departments of agriculture, supports scientific research and also the carrying of research results to farmers. There are one or more extension workers in nearly every agricultural county. The task of bringing their research results to farmers and their families has resulted in the development of a vast field of interpretive techniques.

Similarly the field of cooperative management has stimulated the rise of principles and techniques which promise to increase the efficiency of cooperatives as operating entities.

Corporate Organization

Contributions of science and invention to agriculture are most quickly employed by farmers who are possessed of more than average capital. They are better prepared to buy a new machine or buy better livestock or improved seed than their poorer neighbors. Thus, they gain competitive advantages. In turn these farmers already face sterner competition from larger units adequately financed and employing corporate forms of organization. The larger unit, capable of supporting skilled management and specialists may, in some future time, provide farmers now considered wealthy with competition of equal or greater intensity than that now provided by the latter for farmers on undersized farms, on poor land, or handicapped by heavy debts and other burdens. It remains to be seen whether this will become a trend; the extremely large farm unit so far has not proved its capacity to weather the economic shocks to which agriculture has been subjected.

Commercial Farming Stimulated

The rise in technology has stimulated commercialization in agriculture. Numerous functions have left the farms and are now carried on in population centers, functions which once were an integral part of the farm enterprise. In only a few counties, found in the southern Appalachian Mountains, are self-sufficing farms more common than any other type. In 1929 on most of the Nation's farms more than 80 percent of all farm products were "sold or traded", according to the census.

On more than half of the farms, in 1929, commercial production was valued at less than $1,000. On nearly one-half of the farms the aggregate value of products including those used by the family was valued at less than $1,000.

The other half—those with products valued at more than $1,000—accounted for nearly 90 percent of all products sold or traded in that year. The same group produced 58 percent of all products used by farm families. It is probable that this group could, by utilizing some available technologies and with some increase in the area of land for tillage, produce 10 to 11 percent more—thus accounting for all products "sold or traded."

Birth rates are highest among the half who accounted for only 10 to 11 percent of commercial production. This group had lower cash incomes; in general, occupied poorer land, and employed fewer products of science and invention. Their children, by and large, have fewer educational opportunities and more reason to leave their homes and communities to seek employment elsewhere.

Technical progress in agriculture has a significant influence on birth rates. Technology promotes the division of labor and provides incentives to commercialize agriculture. Commercial experience tends to

emphasize economic considerations. A consciousness of economic considerations tends to sensitize parents to the economic responsibilities involved in a large number of dependents. Technologies, by reducing the need for hand labor in many types of farming, have also lowered the position of children as economic assets.

Competitive Tensions Grow

The advance of technology in agriculture has tended to widen the gap in general well-being between farmers who are able to embrace it and those who are unable to utilize many of the fruits of science and invention. This gap is certain to widen. The hoe has not been relegated to the museum. The man with the hoe and the man with a tractor are not competitive equals where they are engaged in the same type of farming.

There is likely to be growth rather than relief in the tension created by the uneven impact of technology affecting large numbers of agricultural people.

Unrestrained competition will lead toward greater concentration of commercial production on fewer farms with an increase in the average size of these farms and fewer commercial farmers. This would mean an increase in the number of farmers with relatively small commercial production, swelling the ranks of self-sufficing farmers. This group will have increasing incentives for migrating to industrial centers and competing there for existing employment opportunities. These opportunities, unless increased as a result of greatly expanded industrial production, are likely to be so limited that migration would be possible for only a relatively small number of those ready and willing to leave rural areas.

With an increase in the number of rural persons hemmed in by limited opportunity in both city and country, opposition to technological advance in agriculture is likely to grow unless a means is devised to relieve tensions.

Concentrations of land ownership and tenancy in commercial farm production are both increasing in the United States. Many legislative proposals have been advanced to check both trends. Proposals to curb the growth of "corporation farming" have been made in several State legislatures. Programs for assisting tenants and sharecroppers to buy land have been offered, notably in the Bankhead-Jones farm tenancy bill before the last Congress.

Alternative Courses of Action

It has been said that the forces of technology cannot be stopped but they can be directed into more socially desirable channels.

If guidance is attempted, "socially desirable goals" will have to be determined. And this determination rests upon decisions as to the character of agriculture that is wanted.

Should agriculture strive for maximum efficiency in production with larger and larger units, more concentrated ownership and management, and fewer and fewer farmers?

Should it seek to support a larger population with small incomes, with an increase in the number of farms—an increase which would limit the application of technology?

Should it seek some middle ground in which the ideal of "family farms" is uppermost, that would limit, without eliminating, further technological advance?

Is there more justification for imposing a bar to technological advance in agriculture than in the case of numerous industries that have moved out of homes and small work shops into large factories?

Instead of seeking to restrain technological advance would social ends be better served by concentrating on efforts to increase industrial production and employment in the expectation that jobs would ultimately be available to many excess agricultural workers?

The answers will be difficult to find and will necessitate reconciliation between many conflicting attitudes. The prospect of more rapid technological advances in coming years emphasizes the need for the early valuation of the social gains and social costs that are likely to arise out of each course.

II. MECHANIZATION AND ENGINEERING[3]

Mechanization of agriculture depends for general utilization upon economic and physical feasibility. It is stimulated sometimes by scarcity of farm labor, at others by relatively high wage scales, or by the uncertainties and economic risks incident to use of transient labor in harvesting crops with high market value.

The expansion of farming into new lands topographically suited to large-scale methods of production accelerated the mechanization of American agriculture. Scarcity of labor caused by the World War influenced introduction of the combine east of the Rockies, after 40 years in use on the western slope. Development of the automotive and other industries in the North Central States reduced the migratory labor available for wheat harvesting to a degree that encouraged introduction of the combine there.

Industrial developments in the Northern and Eastern States and continuation of the movement of the

[3] Contribution from staff of Bureau of Agricultural Engineering, U. S. Department of Agriculture, S. H. McCrory, Chief.

FIGURE 8. The cradle.

FIGURE 9. A hand-rake reaper.

FIGURE 10. An early horse-drawn combine.

FIGURE 11. A tractor-operated grain binder.

FIGURE 12. A prairie-type combine with auxiliary motor.

FIGURE 13. A small combine operated by power take-off on tractor.

cotton spinning and textile industries to the Southeastern States caused a marked loss in rural population in the latter area. In Georgia the rural population in 1924 was 22 percent less than that in 1919. Cotton production and acreage declined steadily in the Southeast, but it increased rapidly in Texas and Oklahoma where topography is suited to large-scale production and the climate is favorable to harvesting by snapping and stripping, which has become prevalent in that region in spite of the lower quality of cotton harvested in this manner.

The uncertainty of transient labor was one of the reasons for introducing the combine into the Great Plains. The scarcity and unreliability of transient labor, and the undesirably low standard of the large alien portion of it, have been large factors in promoting the development of machinery for growing sugar beets.

If the United States became engaged in another great war, adoption of a mechanical cotton harvester might be expected. The mechanical picker has reached a stage at which, in the face of labor scarcity, it would prove a very important help in harvesting cotton in the volume necessary for major war needs. Extensive use would provide opportunity for refinement in design and lowering of cost, and for adaptation of cotton varieties to machine harvesting. This would have to be accompanied by further adaptations in ginning and cleaning equipment as have been made for the snapped and stripped cottons in Texas and Oklahoma. Machine-picked cotton is inferior to hand-picked cotton and in view of present wage scales, mechanical harvesting probably does not offer a sufficient saving in costs to offset the lowering in quality.

Many mechanizations, such as for producing grade A whole milk and for washing spray residue from fruit, have been introduced to perform higher quality, more satisfactory services than are practicable, or perhaps possible, by hand methods. The effective control of many insect pests, weeds, and plant diseases depends in large measure upon use of mechanical devices.

Farm Labor Efficiency

The development in farm machinery during the past century has greatly increased the efficiency of farm workers. While the total population of the United States increased from 17,000,000 in 1840 to almost 123,000,000 in 1930, the persons engaged in agriculture increased only from 3,720,000 to 10,480,000. In 1840, agricultural workers[4] comprised 77.5 percent of all persons gainfully employed in the United States; since then, the proportion has dropped steadily until in 1930 it was only 21.5 percent.

That the income of the agricultural worker tends strongly to increase with increase in power and machinery available for his use is indicated in comparing by States the average gross annual income, available power, and value of farm mechanical equipment. Alabama has the lowest gross income per worker, $492 including the value of his products consumed by his own household, with 1.5 horsepower available and $142 invested in machinery; Nevada shows the highest income, $2,263, with 9.5 horsepower and $739 investment. Montana shows the greatest horsepower per worker, 22.5, with $953 invested in machinery, and a gross income of $1,798. North Dakota has the highest investment per worker, $1,119, with 18.0 horsepower and $1,806 income. Fragmentary data from foreign countries seem to indicate that throughout the world increase in amount of power available, within the limits observed, tends to increase the income of the agricultural worker.

Rural Electrification

Agriculture, although a large user of mechanical power, has thus far made relatively little use of electrical power as compared with other industries. In December 1935 less than 789,000, or 11.6 percent of American farmers, had electric power available other than individual lighting plants. The average consumption of central-station power per farm varied in 1935 from 558 kilowatt-hours in West Virginia to 11,799 kilowatt-hours in California.

On certain types of farms electricity can be used in many ways to lower the cost of production or improve the quality of products. On dairy farms it can be used for milking, separating, cooling, pasteurizing, sterilization of utensils, and refrigeration of products. On poultry farms it is used for heating incubators and brooders, for illuminating laying houses to increase egg production, and for mixing feed. In market gardening this power is used in pumping water for irrigation and for washing vegetables, in heating hotbeds, and refrigeration for temporary storage of perishables. On grain and livestock farms fewer jobs have been found for electric power, but it can be used for pumping water and for storing grain and hay. Where water is pumped from wells for irrigation of field crops, electric power is used extensively. More than 200 different uses of electricity on farms have been noted. Rural electrification has its most immediate effect in the home.

Experience in other industries indicates that only a beginning has been made in adapting farm operations to economical use of electricity. Further research will make it practicable to increase greatly the farm electric load so that this power will be very profitable to the user. Ultimately, there will be a considerable in-

[4] All persons 10 years old and over, reported by the census as gainfully employed, engaged in agriculture.

crease in the use of automatic and semiautomatic machinery for such purposes as pumping water and operating processing machinery; an extensive use of heating devices for hotbeds and stock-watering tanks; perhaps, air conditioning; and, possibly, substitution of electric for other power in field operations. Rapid extension of power lines to serve farms, which has been started under public auspices, will do much to stimulate progress and will make possible introduction of many labor-saving devices in farm homes. The wise use of electricity in agriculture should lower cost of production, improve quality of produce, lighten the labor of farm people, and make possible more comfortable living on the farm.

Refrigeration

The application of refrigeration to farm products has done much to insure that perishable farm products such as meat, milk, fruit, and vegetables reach the consumer in good condition, and has made possible many improvements in diets. Refrigerator cars and refrigerated trucks provide even the smallest and most remote towns with dependable supplies of fresh meats. Fruits and vegetables can be shipped across the continent and reach the consumer in perfect condition. Refrigeration in transportation has permitted shift of the production of perishables away from the localities of consumption to the regions best suited for growing them.

Household refrigerators have been greatly improved through mechanical operation until they can safely store perishables for considerable periods. Extension of electric power in rural areas will make this facility possible in many homes not now satisfactorily equipped. Gas or kerosene refrigerators can be used where electric power is not available. Experiments with community storage houses in which units of different sizes have been held at agreed temperatures have given indication that such storages would fill a need and be profitable in many communities, particularly in warm climates.

Research is needed to develop small, low-cost refrigerated storages for farmers and small cooperatives, and to work out improved methods of storing perishable products on the farm, so that surpluses of certain commodities can be held longer and a better distribution be obtained.

Farm Buildings

Changes in building types take place slowly because of the long life of well-built structures. In New England, for instance, the majority of farm dwellings were built more than 50 years ago and a great many more than 100 years ago.

In recent years farm buildings have depreciated greatly in value both through deterioration in physical value, partly the result of depressed farm incomes, and through obsolescence. The farm housing survey of 1934 showed about half of the farmhouses needed major repairs or replacement, with the other buildings in about the same condition. Changes in farming methods and in farm production have modified the requirements for buildings, and adoption of automotive machinery in place of animal power, on the farm and in the city, has reduced the shelter and feed storage needed for work stock.

A program of readjustment is needed that will take advantage of new or improved methods in farm-building design and construction and of researches in farmstead planning. Studies have developed arrangements more economical of labor in caring for livestock, and including accommodations for such equipment as feed grinders and litter carriers. The balloon type of barn framing has been developed as more economical than the heavy frames of early days. Concrete foundations and floors instead of the old log foundations and the pole and plank floors, and concrete walks, feeding floors, dipping vats, and other structures have permitted better sanitary conditions and thus contributed largely to more healthful milk supplies for city as well as for country people. Construction methods providing greater safety against fire and storm, and better protection against weather, have been developed.

Use of insulating material on farms is comparatively new but is rapidly being accepted. A better understanding of ventilation, moisture control, air conditioning, and lighting requirements may be expected to bring about changes in building design that will provide greater comfort for man and beast and improved quality in stored products.

Much progress has been made since the day of the pioneer whose large family was housed in a log cabin lighted by candles, heated by open fireplaces which also served for cooking, and supplied with water from the old oaken bucket. Yet the farm housing survey showed that only about 15 percent of the farms have the safety and convenience of electricity; 27 percent have kitchen sinks and drains; 17 percent have cold water piped into the house; 8 percent have piped hot water; 9 percent have flush toilets; 8 percent have furnace heat; and 4 percent have gas or electricity for cooking.

Reclamation of Wet and of Arid Lands

Drainage.—Technology has developed the equipment and methods for building the drains which have con-

verted more than 50 million acres of swampland into farms. Studies of run-off and of hydraulics have determined the drainage requirements of such areas and the fundamentals of designing the drainage works. The 1930 Census reported more than 84 million acres in organized drainage enterprises. The States of Ohio, Indiana, Illinois, and Iowa rank high both in extent of drainage improvements constructed and in agricultural development. Where community drainage enterprises are operating, farm lands as a rule are highly developed.

The drainage work thus far undertaken has reclaimed those lands most easily occupied. There are yet in the United States some 60 million acres of varying degrees of fertility that when needed can be made available for agriculture by drainage. But the cost of doing this will be much higher than that for the land already drained because of unfavorable location, heavy timber cover, or other disability. In their present condition these lands are valuable for grazing livestock, sheltering wild life, or growing timber. When increasing markets, deterioration of hill lands, or other conditions make it desirable, these areas can be drained and brought into cultivation.

Underdrainage has been profitable to farmers, but in the past decade little of such work has been done because of low farm incomes and the extended period of scanty precipitation. There are indications that with return of normal conditions use of underdrains will greatly increase, and that they will become common in many sections where now comparatively unknown.

Irrigation.—Only through application of developments in construction machinery and materials has it been possible to bring water to a large part of the 19,500,000 acres irrigated in the United States in 1930, upon which is so largely based the agriculture of a great portion of the West. The huge dams, canals, tunnels, flumes, and siphons could have been neither built nor designed without engineering technique, and expansion of the productive acreage sufficiently to pay the cost has required further technology.

The supply of water available for irrigation in some sections has been fully utilized, although with complete economy in very few localities. Studies of water requirements of crops and of methods of applying the water are gradually bringing about correction of wasteful use. While irrigation is as old as the Pyramids, only recently have devices been perfected for accurate measurement of flowing water. This achievement has made possible detailed studies of the use of water by crops, losses of water in transit, and waste of water from fields and from canals. It has resulted also in more equitable apportionment of limited water supplies to users, thus eliminating one of the chief causes of friction in irrigated areas.

Areas that can be irrigated cheaply by direct diversion of water from streams have been almost completely occupied. Any large areas yet to be brought under irrigation must be supplied with pumped or stored water. Creation of storages for this usually must be coupled with development of power if the cost of obtaining water is not to be greater than the value of the crops that can be grown with it. Nevertheless, indications are that for several decades the area irrigated will continue to increase, until the practically available water supply is wholly utilized.

Far more effective utilization of waters available for irrigation than has been possible heretofore is being promoted by the making of snow surveys high in the mountains from which streams flow, in the arid region. Irrigation water-supply forecasts based upon measurements of the water in the snow cover enable the farmers to plan their cropping programs so as to get the greatest return from the water that will be available, and permit economical regulation of releases from reservoirs.

Pumping from wells to supplement other water supplies will increase in importance in many of the older, highly developed sections. Expansion of the area so irrigated is encouraged by improvements in pumping equipment, extension of electric power lines, and cheapening of fuel costs. In many areas the drafts upon the underground waters are seriously depleting that supply. Studies of means to increase natural recharge by spreading floodwaters upon porous tracts have met with sufficient success in southern California to encourage ambitious attempts of the same kind in other sections of the West.

Irrigation agriculture, within the available water supply, escapes the greatest hazard of farming in a large part of the United States. Federal irrigation promotion was undertaken primarily to make public lands usable and to foster development of sparsely settled western States. The excessive drought of 1934 stimulated migration from the semiarid region to localities where irrigation is the regular practice. Settlement upon unoccupied fertile lands in irrigation enterprises seems to offer aid in the relocation of people from drought-stricken and wind-eroded areas, and would promote the prosperity of communities that lack farmers to utilize the irrigation facilities available.

In the humid States there probably will be some extension of irrigation for truck crops, fruit crops, and citrus, and probably for other high-priced crops such as hybrid seed corn and nursery stocks.

III. PLANT BREEDING AND IMPROVEMENT[5]

Plant breeding and improvement is technology of a character which has had and will continue to have a significant bearing on processes affecting all agriculture. Research covers many fields, including plant production, plant utilization, and sciences related to them. The range of activities covers practically all plants, wild and cultivated, for which man has found a use as food, clothing and fiber, drugs and medicines for man, or poisons and repellents for insects and diseases.

Improvement in Varieties of Spring Wheat

During the last 30 years extensive efforts have been made to evolve improved varieties of wheat for the northern Great Plains. In 1919 a stem-rust resistant variety was distributed to farmers, but proved unsatisfactory because of weak straw and susceptibility to leaf rust, loose smut, and bunt. It served a useful purpose, however, as one parent of Ceres, a variety distributed in 1926 which has shown great resistance to both rust and drought. In 1935 approximately 5,000,000 acres were grown. Ceres, and Marquis, which was introduced from Canada in 1912 and 1913, are now responsible for an estimated annual increase of 50 to 55 million bushels over the crop that might have been produced on the same acreage with the varieties available 25 to 30 years ago. A new variety, Thatcher—distributed in 1934—is expected further to reduce losses from stem rust in western Minnesota and the eastern Dakotas.

Varieties of Wheat Resistant to Bunt

Bunt, or stinking smut, takes an annual toll of millions of dollars from wheat farmers all over the country. In recent years this disease has been increasing. This disease can be controlled by seed treatment, except in the Pacific Northwest where the organism that causes the disease lives over in the soil. The only remedy there, it seems, is to develop resistant varieties of wheat.

The breeding of such varieties in the past has been complicated by the fact that there are several races of bunt. A particular variety of wheat might resist one or more races of bunt but succumb to others. In recent years a number of varieties of wheat that are resistant to a considerable number of races of bunt have been discovered or produced by scientific breeding. The result may be a material reduction in one of the hazards of wheat growing, with a consequent increase in the security of the farmer and a decrease in his costs of production.

[5] This section was prepared under the direction of S. C. Salmon, Bureau of Plant Industry, U. S. Department of Agriculture.

Hybrid Corn

Extensive field-plot tests in the Corn Belt indicate beyond reasonable doubt that materially better yields can be expected from the use of hybrid seed than is otherwise possible. This increase for the better hybrids is as much as 20 percent for a considerable part of the area under consideration. The plants of most of these hybrids remain erect decidedly better than ordinary corn, a factor of great importance where mechanical pickers are used. Also some of them are more resistant to diseases and insects of various kinds, including the chinch bug, European corn borer, and the corn ear worm.

On the other hand, no satisfactory hybrids have as yet been produced for certain portions of the Corn Belt, particularly the southern fringe. On poor soils and in areas of deficient rainfall where yields are uncertain, the use of hybrid seed may not justify the extra expense. Where corn has come to be the main source of income, however, the extra expense and trouble involved in production of hybrid seed is meeting little resistance. When hybrid corn comes to be widely used, the average farmer probably will buy seed each year rather than try to produce his own.

In recent years the supply of hybrid seed has about doubled each season. Even so, the demand in the Corn Belt has far exceeded the supply. At the present rate of increase there will be 12 to 15 million acres of hybrid corn in 1940 yielding, it is estimated, an average of 35 bushels an acre, or an increase of about 15 percent over present yields. If this development leads to a reduction in acreage, as is thought probable, farm labor in the Corn Belt will undoubtedly be affected.

The Rice Industry in California

Rice growing in the Sacramento and San Joaquin Valleys of California is an example of a new industry developed largely as a result of experimentation. Prior to the inception of research work at Biggs, California, in 1912, no rice of consequence was grown in these valleys. At present, above 125,000 acres are annually devoted to this crop. With average yields of 50 to 60 bushels an acre, the yearly output is now valued at 6 to 7 million dollars.

The Weed Fallow for Tobacco

It is a unique outcome when an apparently careless and slipshod method of growing a crop turns out to be the most profitable. This is about what has happened in tobacco growing. It has been known for many years that under a system of farming in which tobacco is grown in rotation with other crops, better returns are obtained, with certain exceptions, than

from an equal acreage planted to tobacco year after year. It is also well known that some rotations are better than others. Recently, however, it has been shown that a weed fallow, that is, land that has been permitted to lie fallow with no cultivation whatever and with such weeds as will naturally grow, produces a better return per acre than can be produced by the best rotation with a cultivated crop. The yield is better than might be expected, but the principal gain lies in the superior quality of the tobacco. The increase in the value of the crop may be as much as $200 or $250 an acre.

Curly Top Disease of Sugar Beets

West of the Rocky Mountains the sugar beet is subject to a disease known as curly top. It is a virus disease, known since 1897 and transmitted by the beet leafhopper which breeds on weed plants of the desert lands adjoining beet-producing areas. When the weeds dry up in the spring the leafhoppers migrate to the beets. Half or more of the plants may be infected by midseason, and by late summer or early autumn the infection has occasionally spread to the entire crop. During the last two decades the disease has become so serious that it is now recognized as the chief limiting factor to sugar-beet production west of the Rocky Mountains. In 1926 and again in 1929 losses to growers were estimated at from $10,000,000 to $15,000,000.

In 1929, Congress, taking special notice of this threat to a large farming area, made an appropriation for special study. As a result, varieties of sugar beets resistant to curly top have been produced and a beet-seed industry has been developed in the United States. Until recently commercial beet growers in this country had to import their seed from Europe. By careful selection and breeding, resistant varieties have now been developed; a new industry for the United States, the production of sugar-beet seed, is now firmly established.

Improving the Quality of Cotton

About 25 years ago the Bureau of Plant Industry of the United States Department of Agriculture undertook an extensive research program designed to improve the quality of the American cotton crop. Several factors, up to that time, had contributed to its progressive decline. In concentrating on early maturing varieties—in order to escape the ravages of the boll weevil—cotton growers had rather consistently sacrified quality of fiber. In many communities several varieties of cotton were planted in adjacent fields, resulting in cross-pollination and mongrelizing of good and bad varieties. Moreover, the gradual depletion of soil resources tended to encourage a general decline in quality. For more than 20 years experiments have been carried forward, resulting in superior varieties of early maturing cotton where early maturity is a highly desirable quality.

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Along with these improvements from the point of view of quality has gone the development of the single-variety community plan for keeping the varieties pure and producing cotton of superior quality in large even running lots readily available to manufacturers and foreign markets.

Mosaic-Resistant Sugarcane

The history of sugarcane production in the southern United States illustrates in a striking way what can happen to any crop that is grown intensively. About 1908 there began a more or less gradual decline in acreage planted to sugarcane, and a reduction in total output as well as in the output per acre. The principal features of the decline are illustrated in figure 1. Large areas of the best alluvial lands of the Mississippi delta, to say nothing of other less productive areas, remained idle and grew up in weeds. Many factories there were closed and many of the small farms and large plantations were foreclosed.

Several factors contributed to the disastrous decline in production and yields such as, for example, occasional plant diseases. Root rots and red rot had long been recognized as important yield-limiting factors, but the disease situation was not regarded as particularly serious until the discovery of a mosaic disease in 1919. This was soon shown to be a virus disease and to be transmitted from diseased to healthy plants by the corn aphid. Numerous grasses occurring as weeds in sugarcane fields served not only as hosts for the aphids, but were also susceptible to the disease. Moreover, it was shown that the aphids were carried long distances by the wind. From these facts it seemed evident that control could not be effected through the means of seed-cane selection and roguing.

Continued investigation revealed considerable variation in the severity of the disease in susceptible varieties, and a few were found to be immune. One of the latter, known as Cayana, though unsuited for sugar production, found immediate utilization in Georgia, Florida, Alabama, and Mississippi for sirup production.

Many varieties of sugarcane were imported from foreign countries and tested by the Department of Agriculture. Some possessed sufficient tolerance to mosaic and other diseases to justify their use in Louisiana and were distributed in 1924 and 1925. As a result of these introductions the average yield for the Louisiana crop increased from the low figure of 6.8 tons per acre in 1926 to 16.2 tons in 1938, and 18.8 tons in 1929. Still other improved varieties, including

four bred by the Department, were distributed during the period 1930 to 1935.

As indicated in figure 14, the industry seems definitely on the way to recovery.

Recent Advances in Horticulture

As a result of crossing two varieties of tomatoes in 1917, a selection was made which was introduced about 1925 under the name Marglobe. This variety, because of its high resistance to Fusarium wilt and to nailhead rust, has done much to save the tomato industry of Florida and other winter-garden areas.

Cabbage yellows is a serious disease which affects the cabbage crop from Long Island to Colorado. The disease is caused by a fungus that persists in the soil. In 1910 two cabbage plants were selected that had survived the yellows disease on a badly infested field.

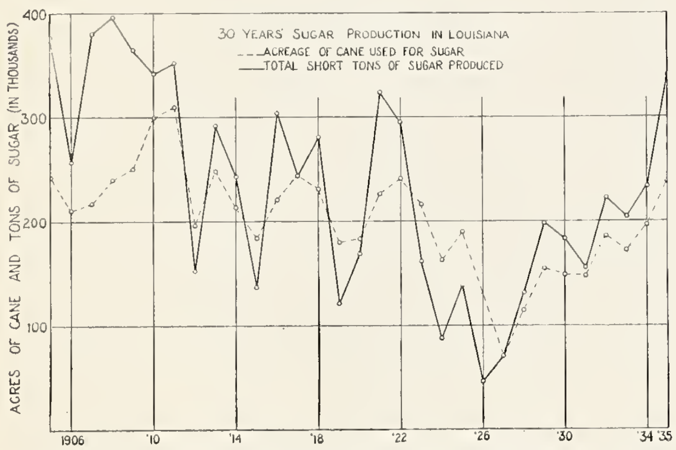

FIGURE 14. Because of the combined damage from mosaic, red rot, and root diseases of the cane, the Louisiana sugar industry suffered a long period of declining yields culminating in virtual bankruptcy in 1926 and 1927. Introduction of resistant varieties has restored the industry, and promises stabilization of production on higher per acre levels following application of the results of further research by the department and cooperating State agencies.

From these, a variety of cabbage strongly resistant to this particular disease has been developed over the years.

Lettuce is subject to two diseases known as brown blight and lettuce mildew. Through scientific breeding, highly resistant varieties have been developed, resulting in a saving of many millions of dollars to the farmers in the Southwest.

And so with other plants. Resistant varieties are constantly being sought out and cultivated with great care, and at the same time a relentless war is being waged against disease and pests.

Soybeans in the Corn Belt

Only about 5,000,000 bushels of soybeans were produced in the United States in 1925 while 10 years later production was in excess of 39,000,000 bushels—a good example of what can happen as a result of constant research and improvement.

The crop was introduced into this country more than 125 years ago, but was never considered more than a forage or feed crop until after the World War. The development of new varieties suited for growing in particular areas, and for particular purposes, has been an outstanding feature of the rapid increase in the crop. Recognition of the value of the crop in dry seasons, immunity to chinch-bug injury, and the increased demand for the crop for industrial and food purposes have been important contributing factors.

Until recently the industrial outlet for soybeans was limited. But in the last few years new uses have been found, as in the manufacture of paints, enamels, varnishes, lard and butter substitutes, linoleum, oilcloth, insecticides, lecithin, disinfectants, core oil, soap, printers ink, medicinal oil, and waterproof goods. Production of soybeans is now a stable and important industry.

IV. TRENDS IN ANIMAL TECHNOLOGY[6]

Our domestic farm animals represent millions of highly adaptable factories for the conversion of raw materials into food, fiber, or power. Both as factories and as storehouses they tend to stabilize the land's production through the seasons and through years of highly fluctuating production.

The purpose of Federal, State, and nongovernmental forces engaged in animal technology efforts is to aid, through research, professional advice or law enforcement, in the fulfillment of livestock's greatest usefulness. It is a constantly changing field in which man's increasing fund of knowledge widens the possibilities, presents new theories and problems for solution, and renders the future difficult of prediction.

The trend is toward greater adaptability of livestock to trying environmental conditions and to man's needs, better utilization of feeds, increased vigilance and skill in prevention of parasite and disease losses, and marked progress toward eradication of the most serious infections from our herds and flocks. The result should be to open new areas to livestock production, to increase the chances for success with livestock in all areas, and to contribute directly and indirectly to human health.

On the other hand many advances in technology in all producing units of the livestock industry seem to be favorable to a trend toward concentration of produc-

[6] This section was prepared by Paul E. Howe, Principal Chemist, and William Jackson, Associate Animal Husbandman, Bureau of Animal Industry, U. S. Department of Agriculture.

tion and commercialization. Strains of animals bred for high efficiency require intelligence, appreciation, and care in their use as breeding stock if their use is to be profitable, for they cost more to produce than inferior or unproved stock. Carefully planned rations must be fed to make the greatest use of the animals' inheritance. The greater drain on the animals' constitutions resulting from high production calls for double precaution in feeding and management or the result may be greater susceptibility to disease.

The producer who can succeed in breeding efficiency into his flock or herd will have a tremendous advantage over the one who does not. Registered Shorthorn steers in controlled experiments have required as few as 373 days and as many as 566 days to reach a live weight of 900 pounds—a difference of more than 50 percent. Similar differences have been found among swine and probably exist among sheep. The average hen in flocks of this country produces only about 80 eggs a year according to census estimates, while superior flocks of progeny-tested birds produce more than 200 eggs a year. Neither geneticists nor practical breeders have found a way to reproduce efficiency without fail, but the possibilities in that direction are increasing, as shown by many encouraging results, particularly with poultry, dairy cattle, and swine.

The production and proving of superior germ plasm in farm animals is expensive, and will probably continue to be for decades to come. This also tends to concentrate superior stock and to encourage larger production units under highly skilled management. But a number of eventualities may result in discouraging concentration of production, and aid the smaller producer.

One of these is the development of breeding farms from which will be distributed superior germ plasm, possibly by mail, in capsules. However, such a possibility will, in itself, mean a highly specialized concentration of superior breeding stock on a few farms producing such germ plasm. It is also possible that the larger producers will make most of such a development.

Another effect toward decentralization of production is to be found in breeding studies to develop types of animals suited to regions of harsh environment, and in nutrition studies to find correctives for mineral and vitamin deficiencies of the pasturage, crops, or water of deficient regions. An example of the first is the work being done by both public and private experimenters in crossing the Guzerat and Africander breeds of cattle with our beef breeds of British origin to develop strains of cattle better adapted than we now have to trying conditions of heat, sparse vegetation, and insect and parasite menace in the South and Southwest. Examples of the second are studies of rations that will compensate for iron deficiency in grazing areas in Florida; phosphorus deficiency in the coastal plains region and the Southwest; iodine deficiency in the goiter regions of the Northwest; and studies of protein, mineral, and vitamin content of forage and harvested crops at various stages of immaturity and under advanced methods of preservation and handling.

A third trend seemingly inimical to great concentration is found in the greater possibilities of infection when animals are crowded. Both concentration and unlimited forcing of domestic animals and poultry for higher efficiency make it difficult to maintain vigor in breeding herds and flocks. Despite improvements in feeding and sanitation practice with swine during the last two decades, the best available information shows that there has been but little change in the average number of pigs weaned per litter. Advances by progressive farmers have apparently been counterbalanced by recessions among careless farmers.

A study of a group of Illinois farms where the McLean County system of swine sanitation was followed showed 5.8 pigs weaned per litter as compared with 5.4 pigs per litter on farms practicing no especial precautions. There was also a saving of feed amounting to 1½ bushels of corn per pig fed to market weight in favor of practicing sanitation. There is evidence that the McLean County system or some modification of it, and the greater use of pasturage have been adopted by swine growers in many sections of the country. In general, pigs raised under the sanitation system develop more rapidly and have a greater market value at a given age. And when the system is followed closely, as many pigs can be weaned and raised from two sows as from three under ordinary methods of swine management.

Although parasites of livestock are widespread in practically all sections, economic loss from them is intensified in the South for such reasons as a favorable climate, an abundance of moisture, and the presence of insect intermediate hosts favorable to their multiplication and spread. In the ordinary run of hogs raised in the South, kidney-worm infestation is widespread.

From 85 to 90 percent of the livers and about 90 percent of the kidneys are infested. Such worms reduce the host animal to a state of unthriftiness characterized by stunted growth, appearance of malnutrition, and a predisposition to disease because of lowered vitality. Research has developed a method of kidney-worm control whereby these losses can be sharply curtailed and can be eliminated eventually if the control measures are followed explicitly.

Nation-wide efforts to eliminate altogether the presence of some of the worst livestock scourges are meeting with gratifying success. Ninety-one percent of

the original cattle-tick quarantined area of over 700,000 square miles has been freed of ticks and released from quarantine in the 29 years since the campaign of eradication began, and the infested areas have been reduced to a total of 62 counties and 6 parts of counties in 3 States from the beginning of 985 infested counties in 15 States.

The degree of infection of tuberculosis among cattle has been reduced from approximately 4 percent in 1922 to less than one-half of 1 percent, with all the counties of 40 States now in the modified-accredited area. The fight against Bang's disease, or infectious abortion, is just getting well under way in this country, with about 700,000 head of cattle being tested each month, on a voluntary basis, and an indicated infection for the entire country of from 13 to 15 percent.

A number of diseases and parasites of animals such as anthrax and certain species of hookworms are direct menaces to human health. Beef and pork tapeworms are acquired by humans as a result of eating raw or improperly cooked beef and pork, respectively. Creeping eruption, a painful and troublesome skin disease of man in certain parts of the South, is due to the invasion of the human skin by larvae of species of hookworm parasitic in dogs and cats. Control measures developed in recent years have helped to cut down such incidence of infestation of man. Quarantine measures, at our ports of entry from foreign countries, and inspections at public stockyards, are aiding in the prevention of outbreaks that can be of serious social consequence.

Man's constant effort to increase the output of his animals, and particularly the tendency in some branches of the industry to concentrate in large production units, is bringing new problems in disease and parasite prevention and control. For example we have the "poultry factory", with thousands of breeding, hatching, brooding, laying, and fattening units in close confinement under one roof. As an outgrowth of the development of artificial incubation and brooding which began about 30 years ago, fully 700 million, or nearly half of the chicks hatched annually, today are produced by commercial hatcheries. An increasing percentage of these are being raised in multistoried houses or similar close confinement, without access to sunlight or free range; in air-conditioned rooms kept at even temperature, and lighted by red bulbs, for chicks, to prevent cannibalism; with vitamin, mineral, and protein supplements provided to offset the absence of sunlight and diet deficiencies due to confinement; and with segregation of adult birds from one another and from the droppings, and periodic sterilization of the cages with live steam to avoid losses from diseases or parasites.

A new development is the possibility of determining the sex of chicks when hatched, permitting a further specialization. About 70 percent of the Leghorn chicks hatched this year on the Pacific Coast were sexed, and a considerable percentage of the cockerels killed at once. The man who is in the poultry business for egg production only can now purchase day-old pullet chicks, enabling him twice the number of pullets with the same expenditure of feed and labor, and with the same equipment. The sexing of day-old chicks in the Middle West is already acting to stimulate commercial broiler production, which will likely in turn affect the production of roasting chickens.

A study of data from all parts of the United States shows a tendency for pullets and hens that are being forced for egg production to be much more susceptible to disease. Records from 1928 to 1933 on 126 farms in San Bernardino County, Calif., averaging 956 hens per farm, show an uninterrupted increase in laying-hen mortality from 19.49 per cent in 1928 to 38.9 percent in 1933. Records of mortality among pullets and hens in egg-laying contests show an increase of from 11.5 to 16.3 percent in 7 years in Connecticut; of from 13.2 percent in 1921–25 to 55.5 percent in 1929–32 in Ohio; of from 14.0 to 26.6 percent in 9 years in Georgia; and from 6.58 to 24.77 percent in 14 years in New Jersey.

Studies of the causes of these losses show that disease is the most important, and that diseases of the egg-laying function of the bird are the most prevalent of all diseases. The underlying causes are greater opportunity for spread of infection when animals are concentrated in small space and failure of advances in technology to compensate for the forcing for production under conditions of unnatural environment. Both of these causes seem correctable. The uncertain quantities are man's ability to make full use of his own technological advancement, and his willingness to do so. There is a point beyond which precautions cost more than they are worth; and men are careless.

Much progress in animal product technology has taken place. New uses have been found for animal products and valuable guides have been developed to improve production practice. A recently invented device for determining wool fineness and cross-sectional variability has been found useful also in the cotton, silk, and rayon industries. It promises to do much toward coordinating the aims of the producers of fibers with the needs of the manufacturers and the users of the finished fabrics. Human medicine has developed some amazing uses for animal glands and gland extracts: the pancreas to supply insulin for treating diabetes, the adrenals to supply cortin for treating Addison's disease, the parathyroid to supply parathormone for treating abnormal calcium metabolism,

the anterior pituitary or its extract for treating various sexual disorders and use in gynecology. Meats and meat-food products have been cured, processed, and merchandised in a great variety of more useful and more attractive ways, and recently the widespread extension of the use of subfreezing temperatures for the storage of fresh meats promises a new means of storing surpluses for times of scarcity, and of the use of fresh meats in all parts of the country at all times of the year.

Summing up, it is probably fair to say that the time is decades distant when technology will give man a sure command of the production of livestock for specialized purpose and to fit specialized agricultural conditions, such as he enjoys with many plant crops and with mechanical inventions. Animal germ plasm and behavior are less amenable to man's genius and will than are plants and machines. But it is possible that the many problems yet to be solved in animal technology obscure the fact of current progress.

The geneticist and his ally, the experimental breeder, have produced livestock and poultry of great practical efficiency, and the nutrition specialist has cooperated to develop means of making meat, milk, and eggs of especial usefulness for food.

This country is freer of serious livestock pests than most countries, and is making greater progress toward a clean bill of livestock health than perhaps any other. The livestock quarantine and meat-inspection services are unexcelled anywhere in their service to both producers and consumers of livestock and livestock products.

Our civilization, like our animal husbandry, is highly artificial, and might decline rapidly without the constant application of research to the problems that are arising. Without the aid and protection afforded by science, disease would speedily result, in all likelihood, not only in a decline in the production of meat and milk and other animal products, but also in a decline in human population, particularly in cities.

Health and security are major objectives of the human race. Domestic animals and their products, with the benefit of man's research and technology, seem to offer increasing aid toward those objectives.

V. INSECT PESTS AND THEIR CONTROL[7]

Insect pests affect man's every activity. They destroy his food plants, his livestock, his clothing, his buildings, and indirectly through insect-borne disease, affect man himself. In the United States alone the annual tax paid to insect pests attacking agricultural crops and livestock often amounts to over 2 billion dollars. The cotton boll weevil, for example, destroys an average of nearly 2 million bales of cotton every year; the hessian fly takes an average annual toll of 48 million bushels of wheat.

Scope of Insect Control Work

The most conservative estimates give the number of insects as about 4,500,000, of which only 750,000 have been described. Not all of these are detrimental to man. Some, such as the honeybee and those which prey on other insects, are beneficial. The destructive and annoying kinds number hundreds of thousands, however.

More than 7,000 species cause economic losses to crops in the United States. The habits and hosts of these all differ and controls vary with the kind of pest, region, and crop. The methods employed include the use of natural enemies, the adaptation of modifications in crop practices, the determination of tolerant or resistant varieties of crops, the use of mechanical devices, the use of poisons, attractants and repellents—in fact any device, material or agency which can be economically applied. In the use of insecticides alone developments in economic entomology have brought the control of insect pests from hand-picking and the sprinkling of a simple insecticide with a whiskbroom to the high-powered sprayers that reach the highest shade trees and the permanently installed spraying equipment by which several hundred acres of orchards can be treated from a central spray plant, and the airplane duster that can cover several cotton plantations in one day.

The field of insect control is very broad. It requires an extensive and specialized technique and the use of detailed knowledge in many fields of endeavor and science. To coordinate and use these effectively to a common end requires detailed planning. There is the intricate technique of rearing the insect to determine its habits, responses, and hosts; the development of ways of producing insect parasites under artificial conditions, of transporting these parasites sometimes half way around the earth, of cultivating these insects as pure cultures, and of successfully introducing them to the field. The work on bee culture requires specialized technique in handling the bees, in studying honey quality, wax production, and the artificial insemination of queens to produce improved varieties. The devising of mechanical and chemical ways of combating insect pests, such as the development of practical traps or new insecticides; improving and adapting spraying and dusting equipment to special agricultural practices and insect conditions;

[7] Prepared by the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Lee A. Strong, Chief.

devising fumigation tanks, steam sterilizers, refrigeration plants, and other devices for treating plants and plant products to free them of insect pests at the ports of entry in order that their introduction may not serve as a means of establishing in this country noxious pests from foreign lands involves the use of highly specialized technique.

Even brief description of the steps involved in developing various methods and planning operations for the control of insect pests would require many pages. Such a discussion would include reference to the principles involved and the technique used in the development of methods and programs; an explanation of the mechanics in making results available for application by individuals and governmental agencies.

The control of insect pests is increasing in complexity. The achievements of the past give assurance of future developments to meet ever-changing conditions. The constant development and change in agriculture and improvement of public health accompanied by the ever-increasing insect consciousness contribute to the complexity of the problem of insect control. The placing of large areas under cultivation and erecting cities and towns have contributed to making favorable environments for insects which in earlier times were of little importance. The rapid development of methods of transportation materially increased the opportunities for dangerous pests being transported to new areas.

The vision of the entomologist is being modified to meet these changing conditions. Lines of investigation little thought of in the early days are under way and basic studies on evironmental influences have been begun. That the work on insecticides will develop materials effective against insects attacking food products without leaving residues hazardous to the consumer seems only a matter of time. Who can say that more intimate knowledge of the environment favorable to grasshoppers will not permit some slight adjustment such as the elimination of some plants favorable in the development of grasshoppers which are of little importance as crops that will prevent general outbreaks of these pests.

Full understanding of the effect of radiations on insects may lead to the development of controls for many pests of households and storages without resorting to control measures now used requiring the application of powerful gases with accompanying health hazard.

VI. WEATHER AND FORECASTS[8]

Weather Forecasting

Weather forecasting, as now practiced by most civilized governments, is of enormous and increasing value to mankind. Great efforts are in progress in America and elsewhere to improve its efficiency and especially to extend the range of forecasts, so that the character of coming months and seasons may be successfully foretold. There is every prospect that this technology will be much more useful a few years hence than it is today. If, however, we are asked to project our view into the more distant future, we must contemplate the possibility that these techniques may diminish in practical value even though they may increase in accuracy.

Half a century ago a vast acreage in the tropics was devoted to growing indigo. The crop was sometimes damaged by drought. Accurate long-range forecasts of droughts might have made these events less harmful to the indigo-grower, though they would still have caused him serious trouble. Today drought has little effect on the production of indigo because it is nearly all made in factories from coal tar. Many other dyes, drugs, perfumes, leather substitutes, and bone substitutes, are now similarly produced. Weather has no influence on their production.

[8] This section was prepared by the late C. F. Talman, Meteorological Consultant, Weather Bureau, U. S. Department of Agriculture.

Many more industries may be transferred from the field to the factory and thus be made weatherproof. Transportation by land, sea, and air will be made more and more independent of weather. The discomforts of weather have already been minimized by the artificial control of weather indoors, where most of us spend nine-tenths of our lives. It would seem that, in proportion as mankind becomes less susceptible to the harmful effects of weather, the importance of predicting the latter will decrease, though it may never reach the vanishing point.

Reverting to the present situation, while it cannot be honestly claimed that weather forecasts are now rapidly improving in accuracy, a strongly optimistic feeling that they soon will prevails among meteorologists. This is founded on the fact that methods of forecasting recently introduced are definitely scientific, as contrasted with the empirical methods developed in the nineteenth century.

There have been three stages in the history of weather prediction. In the first, dating from remote antiquity, purely local indications were relied upon to furnish clues to the coming weather at the place of observation. In the second, beginning a few decades ago, charts of weather occurring over extensive areas, drawn from telegraphic reports, enabled forecasters to apply a number of rules, derived from experience,

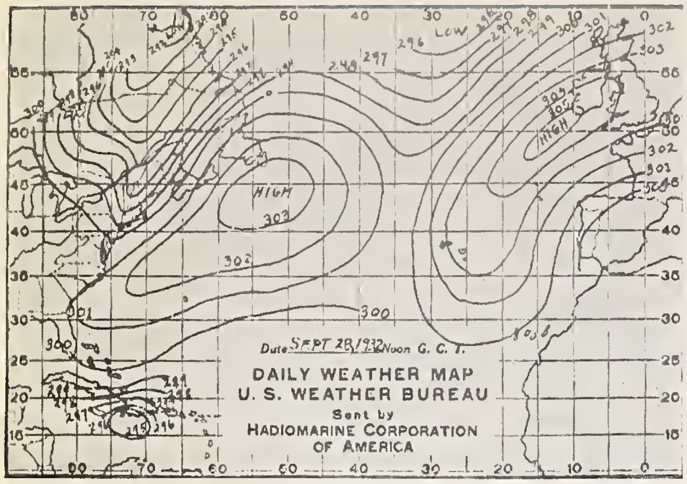

FIGURE 15. Weather map of the North Atlantic Ocean as prepared in New York and transmitted by facsimile radio to a ship in midocean.

concerning the relations of weather in one region to weather in another. The rules frequently failed to work, and the physical principles underlying them were, in general, unknown.

The present era can best be described by saying that forecasting is now being rationalized. The forecast still requires the preparation of a weather map, but on this map it is now customary to mark the locations of so-called air masses, differing from one another in their physical properties—especially temperature, moisture content, and direction of movement—and not merging gradually into one another, but bounded by abrupt discontinuities, called fronts.

The interplay of air currents along these fronts explains the origin of the "lows" seen on the weather map and the distribution of rain, clouds, and other weather conditions surrounding them. Most significant, however, is the fact that the physical factors involved in weather processes, as thus conceived, are susceptible to somewhat exact measurements—derived partly from observations taken, from airplanes or otherwise, at high levels—and these processes are amenable to analysis according to the methods of mathematical physics. Within still modest limits, future weather has become calculable. The whole story of how this has come to pass would take up far more space than is here available.

Attempts at long-range weather forecasting have also entered a new era. Having formerly been regarded, to say the least, as "bad form" on the part of conservative men of science, they are now engaging the attention of first-rate minds in many parts of the world. Some of the methods proposed aim only at a moderate extension—by a few days or a few weeks—of the present range of forecasts. These are in some cases based on weather maps covering a large area of the globe, on which the forecaster watches developments at so-called centers of action, which appear often to furnish clues to following weather in regions remote therefrom.

Many attempts have been made to predict the general character of coming seasons, especially as to temperature and rainfall, from relationships that apparently exist between weather abnormalities in certain parts of the world and the weather abnormalities occurring months later elsewhere. These supposed relationships are called teleconnections, and the degree to which each of them holds good, in the long run, as shown by past weather records, is expressed numerically as a correlation coefficient. A seasonal forecast for any region is based on a combination of several teleconnections applicable thereto that have been found to show high correlation coefficients. The classic example of such forecasting is the official announcement concerning the character of the summer monsoon rains in India, which has been prepared each spring for more than half a century; with, however, only a moderate percentage of successes. It is based on teleconnections extending halfway round the globe.

Still other long-range predictions are founded upon the belief, still unproved, that curves of weather variations, when suitably analyzed, reveal certain regular cycles or periodicities, sufficiently stable to be counted upon to repeat themselves indefinitely in the future.

Probably the majority of meteorologists cherish little hope that these or other proposed methods of long-range forecasting will ever prove successful, except, perhaps, in increasing the present range of predictions

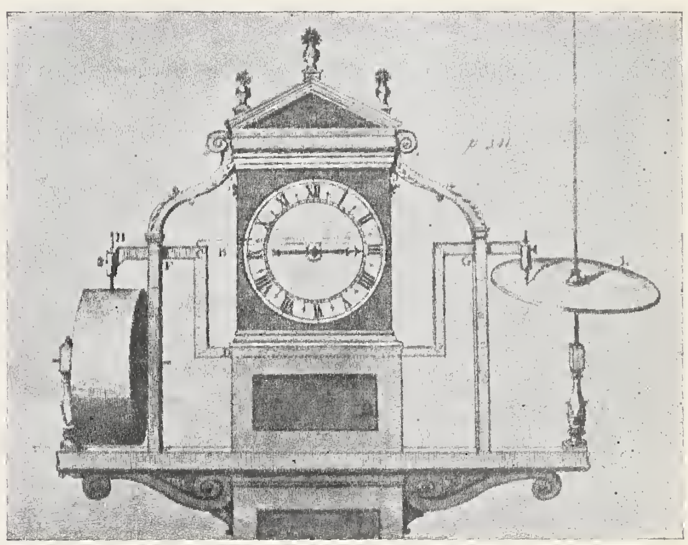

FIGURE 16. Sir Christopher Wren's weatherclock (1663). T. Sprat, in his History of the Royal Society, writes of Wren's invention: "Because the difficulty of a constant observation of the air, by night and day, seemed invincible, he therefore devised a clock, to be annexed to a weathercock, which moved a rundle, covered with paper, upon which the clock moved a black lead pencil; so that the observer by the traces of the pencil on the paper might certainly conclude that winds had blown in his absence for 12 hours space."

FIGURE 17. A modern meteorograph, which makes a continuous record of wind direction and velocity, sunshine and rainfall.

to a slight extent. On the other hand, it is generally recognized that meteorology is under an imperative duty to the public to exhaust all efforts to reach this long-sought goal, unless somebody can demonstrate that its attainment is absolutely impossible.

With respect to this venture the meteorologist is apparently in the position of a gambler who, at the cost of a moderate stake, earns a chance, however small, of winning a colossal fortune.

Weather forecasts, as now issued, though brief in their range and frequently faulty, are valuable to the community because, in an endless variety of ways, people adapt their undertakings to the predicted weather, and in the long run the forecasts are far more often right than wrong. The value of the present forecasts certainly implies that accurate long-range forecasts—even in quite general terms as to place and time—would be correspondingly more valuable in any nation suitably organized for guiding the undertakings of its citizens according to the distant weather program. Forewarned is forearmed. A country can take measures to mitigate the disastrous effects of a droughty summer or a severe winter, if foreseen months in advance, just as it can take steps to repel an alien army that has announced its intention of invading the country.

Weather Recording and Reporting

The vast business of observing weather and interchanging news about it is one of the most spectacular products of civilization. It is estimated that there are in the whole world upwards of 40,000 weather stations—places at which weather is observed, once a day or oftener, with the aid of one or more instruments—as contrasted with a few hundred in existence a century ago. This estimate includes, in addition to fixed stations on land, possibly 4,000 mobile stations on ships, operated according to standard methods under the direction of official meteorological services. Apart from these regular shipboard stations, all other ships enter weather notes in their logs, but the information thus recorded generally remains unutilized by the world at large.

The majority of weather stations are maintained for the purpose of collecting climatic data—statistics concerning the weather conditions characteristic of different localities. Such data are used for three principal purposes; first, in the investigation of meteorological problems; second, in the investigation of the relations between weather and various nonmeteorological phenomena (the relations of weather to health, for example); and third, as a means of anticipating in a general way the weather of the distant future, so that human activities may be planned in accordance.

Climatic data are essentially long-range weather forecasts, and the most trustworthy that we possess at present. Farming operations are planned on the basis of past experience of weather in the region concerned, as embodied in climatic statistics. Travelers for health or comfort go to places where the records of climate show that, in the long run, the most desirable weather conditions prevail. Marine routes and airways are located in accord with similar information.

A few thousand weather stations, besides contributing to the statistics of climate, transmit reports of their observations by wire or wireless telegraphy to centralizing points, and there is a further interchange between these centers. Such reports are intended primarily for the use of forecasters, but they are also used by persons who, for one reason or another, desire information concerning current weather at distant places, rather than forecasts.

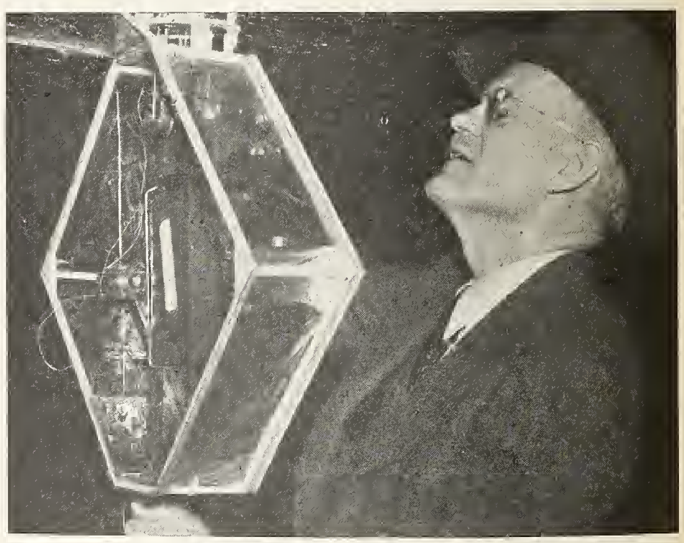

FIGURE 18. A radiometeorograph attached to a sounding balloon. At regular intervals throughout the ascent and drift of the balloon this device reports by radio signals the barometric pressure, temperature, and humidity encountered along its course.

A remarkable international weather news service, operated by means of thoroughly coordinated radio broadcasts, has lately come into existence. One result is that it has become possible to chart current weather, by land and sea, over a large part of the globe. This international system is supplemented by intensive systems of weather reporting in particular areas, especially along airways.

The advent of aviation introduced a new era, in which reports are assembled at brief intervals, day and night, from closely spaced points of observation; and the intensive news service thus developed for the benefit of aviators becomes more and more valuable to the public at large.

A novelty in the transmission of weather news is the use of facsimile radio. This process is employed in a small experimental way for transmitting weather maps and weather bulletins. Hitherto reception of these documents has been limited to a few ships and airships, but as the process is perfected it promises to become much more widely available. It will place weather maps, drawn by experts, promptly at the disposal of many persons who now, when they need such documents, must draw them themselves from the numerical data transmitted in radio broadcasts, a troublesome task and one that, in the average case, is not very accurately executed by the layman. In the United States facsimiles of current weather maps are transmitted by wire for publication in newspapers.

Two other trends in the observation and recording of weather may be mentioned. First is the technical improvement in the compilation of climatic statistics and weather records and their subsequent utilization through the use of tabulating machines (the "punch card" system). Second, the geographical distribution of weather and climate is now registered in certain regions and for particular purposes at numerous points separated by very short horizontal and vertical distances; as short, in some cases, as a few feet. Such procedures are classified under the terms "micrometeorology" and "microclimatology." They are employed, for example, in determining consistent differences between the minimum temperatures occurring at a given time at different points in a fruit-growing area. A horticulturist may adapt a general prediction for such an area to his own orchard or particular parts thereof, and thus make economical use of orchard-heaters as protection against frost. A number of analogous "temperature surveys" have been carried out for other purposes, and there have been intensive studies of the local variations of wind, rainfall, and other elements.

"Robot" Weather Observers

The substitution for the human weather observer of an instrument that makes a continuous or intermittent automatic record of one or more meteorological elements is hardly a new development, since one of the earliest instruments of this character was the "weather-clock" devised by Sir Christopher Wren in 1663. Such instruments came into extensive use in the latter half of the nineteenth century. In more recent years a number of instruments, known as radiometeorographs, have been introduced for the purpose of transmitting automatic records of meteorological conditions by radio. These reports in some cases are automatically registered at the point of reception. Heretofore this system of reporting and recording weather has been employed chiefly in connection with the flights of sounding balloons, but the same method can be used for obtaining reports from places at ground level where it is not feasible or convenient to maintain human observers. A few installations of this character already exist.

We may expect to see the existing vast network of weather stations greatly enlarged in the near future by means of these devices. It has been proposed to attach some of these "robot" stations to buoys anchored in shallow portions of the ocean or to beacons, analogous to lighthouses, high enough to protect the instruments from disturbance by waves. Others will probably be placed on islands, and still others on mountain tops.

Lastly, a plausible plan was worked out a few years ago to install some of them (dropped from an airship) on drifting ice in the polar seas. In this case the drifting station would be operated in connection with two fixed stations on neighboring shores from which, by means of radio bearings, its position could be obtained at the time of each report. The radio transmitters of such stations are operated by storage batteries. It is claimed that some of those already designed will be able to operate three times a day for a period of 2 years without renewal, and to function at the low temperatures of the polar latitudes.

Whatever advantage accrues to mankind through the maintenance of weather records at numerous points on land and sea should increase in proportion as the use of this new procedure becomes more general. One of its promising applications is as a means of securing reports of barometric pressure now urgently needed in the oceanic areas subject to tropical hurricanes to supplement the somewhat meager radio reports received from ships.

Controlling Atmospheric Environment

The subject of controlling the atmospheric environment and of the physiological benefits likely to result therefrom is enshrouded in controversy. Nevertheless, a number of facts that have lately come to light seem to suggest future possible developments that, in their

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value to mankind, may throw into the shade all other applications of meteorological knowledge.

The perennial dream of controlling outdoor weather is not likely to be realized, except on a small and local scale, short of some millennium of unlimited scientific achievements. On the other hand the control of atmospheric conditions indoors—which began when primitive man built a fire in his cave to keep him warm—has recently made startling progress.

Indoor climates are now modified at will, within wide limits, for the promotion of health and comfort, with respect to temperature, humidity, air movement, and the amount and quality of light. This is true not merely in the dwellings and workplaces of mankind, but also in ships, railway cars, and other vehicles. Indoor atmospheres are kept clean and germ-free. Interesting experiments have been made in regulating their electrical condition (ionization) and some serious investigators claim that the "freshness" of air can be thus maintained, and even that the process can be employed successfully in the treatment of disease. Lastly, it is conceivable that the chemical composition of indoor air may be altered to the advantage of the health and efficiency of those who breathe it.

VII. SOIL: ITS USE AND CONSERVATION[9]

Utilization

Major developments in fertilization, liming, tillage, drainage, irrigation, and erosion control methods have their roots in western Europe as recently as 200 years ago. Slightly earlier, advanced minds attempted to arrive at the "Principle of Vegetation", with conflicting results as testified to by the theories advocated for water, saltpeter, air, fire, and fine earth.

The fallowing of one-third of the land was a long established feudal practice because of the low productivity of the soils for grain. Owing to the insistence of Jethro Tull, inventor of the drill and horse hoe, that cultivation of the soil was imperative for plant growth, a change in methods preceded a change in crops. His teachings were accepted to the extent that turnips were introduced to facilitate cultivation of the soil given to grain production. As turnips were best utilized as feed for livestock, increased numbers of livestock furnished an increased manure supply. Yields increased and more livestock were kept. Grasses and legumes were introduced, and a succession of crops known as the Norfolk system supplanted the fallow system.

This change from a system of grain following grain with every third year in fallow to one of a rotation of crops doubled wheat yields, from 10 to 20 bushels. It was an important revolution in agriculture. Commercial fertilizers were as yet unknown. They are not to be confused with the liming and marling practiced under the Norfolk system.

Fertilization, by other than animal manures, owes its development largely to Liebig who in 1840 in a report upon "Chemistry in its Application to Agriculture and Physiology" denounced and eventually killed the humus theory which stated that plants obtained carbon only from the soil. Believing that plants obtained a sufficient supply of carbonic acid from the air, Liebig introduced the mineral theory which stated that plant growth was related directly to the quantity of mineral elements in the soil. This doctrine gave added impetus to the "Balance Sheet" theory of nutrition which owed its beginnings to the careful experimental work of Boussingault who had conducted research on his farm in France upon the gain and losses in soil nutrients under various rotations.

Lawes and Gilbert at Rothamsted at a later date pointed out that the ash content is not a reliable index to the nutritional needs of a plant. Contradictory results with the nitrogenous requirements of plants when legumes were included troubled investigators until after the rise of bacteriology. The development of bacteriology and its agricultural applications form an interesting chapter of agricultural history.

Relation to Nutrition

With the progress of time the scope of investigations upon the questions of fertilization and technique of application have become more profuse and interlocking. Studies on the availability of phosphates and potash, the roles of the minor elements in nutrition, effect of placement of fertilizer in relation to seed and growing plant, recognition of physicochemical processes in soil and plant colloids, realization of inherent differences of productivity in soils for plants, combined with questions of the economic feasibilities of practices, illustrate some of the branches of current fertilizer science. Recent trends of interest in fertilizer practice extend beyond the plants to the health of the animals and people who eat them as affected by their composition. Especially is this being considered in the dairy industry with studies in pasture fertilization. It appears probable that in the future certain physiological and morphological differences among mankind from various geographical regions may be explained by nutritional differences which in turn may be explained by differences in the

[9] The first part of this section (Utilization) was prepared by J. K. Ableiter, Senior Soil Technologist, Bureau of Chemistry and Soils, U. S. Department of Agriculture. The second part (Erosion Control) was prepared by Leland Barrows, Special Assistant, Soil Conservation Service, U. S. Department of Agriculture.

availability of the plant nutrients occuring in the respective soil types of those regions. Thus scientific research will continue to study the soil-plant relationships which center about the prenomena of plant feeding in the localized areas of contact between the root hair of the plant and the colloidal particle and solutions of the soil. Definite practices in fertilization will attempt to meet the individual needs of plants and soil types for particular chemical nutrients. The importance of the form, availability, and concentration of phosphate fertilizers will be stressed, as will also the economic advantages of higher concentrations of mixed fertilizer. The role of minor elements in nutrition will become important as more nearly pure chemical fertilizers are placed on the market.

With the establishment of the role of bacteria in soil fertility and their soil requirements, liming became more vital to successful farming on the acid soils of western Europe and eastern United States. Studies of soil acidity led to arbitrary methods for the determination of lime requirement and opened wide the field of investigation on the phenomenon of base exchange and the mineral constituents of soil colloids and base-exchange material. Indeed the conflicting data and theories of today concerning the structure and composition of the colloidal soil complex challenge the investigator, and it is not too much to expect that future scientists will be enabled to comb out the tangled skeins of evidence now presented and formulate a more intelligent management of individual soils.

Tillage, as a technique, has been improved consistently since the days of Tull. Straight and deep furrows and finely conditioned seedbeds had been the criteria of good farmers, without question, until these practices of the native forested areas were carried onto the drier grassland areas where a different climatic regime and different soils demanded other practices.

Problems of Land Use

After the opening of the grasslands to settlement, came power machinery suited for extensive operations. Only recently have manufacturers and financiers realized that economic and social stability was threatened by optimistic high-pressure salesmanship in these open grasslands which beckoned so promisingly. Changing points of view on tillage are evidenced by the discard of the dust-mulch theory. Sweeping generalities are being amended, and practices are being made to conform with climatic and soil conditions and economic trends. Tillage practices, land utilization, and social tenure of land are closely interwoven. The future gives promise that science will be permitted to develop programs of wiser land-use throughout the Nation, particularly in the Tennessee Valley and in the semiarid regions where past practices have proved to be economically hazardous. However, the tremendous social implications decree that time is needed to make the necessary voluntary readjustments.

The soils of western Europe and eastern United States have common characteristics, in that they are relatively low in inherent productivity, are acid, are low in organic matter, their structure is easily destroyed, and they did not lend themselves readily to agriculture in their native forested state.

The efforts to increase their productivity were made by men who looked on the soil as a static and unchanging medium deficient in one or more components, as compared to an ill-defined standard of perfection. In certain ways these efforts may be looked on as a study in soil pathology. Thus, much research was given to the study of the chemical and textural compositions of soils without a consideration of their genesis or evolution, other than as geological material containing certain and lacking other specific elements of nutrition which could be corrected through the techniques discussed.

Relative to the influences of the present techniques on the future developments in agriculture, it is essential to note the rise of pedology in Russia and the influence of its teachings on the scientific thought of soil technicians and agronomists in the western world. This science considers the soil as a natural body, dynamically responsive to the environment of which the active factors for soil development are the climate, the vegetation, the relief, the age or length of time the environment as such has been active, and the parent material. Although it is recognized that the marked characteristic of the soil is its productivity for plants, the soil is not looked on exclusively as a medium for plant growth, but rather as a distinct entity whose physical and chemical characteristics have been shaped by an accord with the environment. Hence the soil of a specific area is not lacking, according to some standardized concept, but is the accompaniment of a certain environment with a characteristic inherent productivity for certain plants.

Accordingly soils are studied as objects in themselves, and differences in the structure, color, depth, and texture of the various horizons are noted. This has led to the establishment of soil types, defined by certain physical and chemical characteristics which have been developed by the environment. It follows necessarily that soil types are limited in geographical extent, according as one or more factors of the environment may change. This newer concept carries the thought that all techniques of crop and livestock production are ultimately concerned with specific soil types as units of the landscape, having

a distinctive profile, native vegetation, range of relief, drainage, response to fertilizer, inherent productivity, adaptations for crop plants, and other features.

One of the technological trends of the future appears to be the more exact mapping and study of these land units, or soil types. Research will be conducted on their chemical, physical, and biological characteristics as they pertain to crop plant growth and production. This means further intensive study in the laboratory, experimental plot, and the farmer's field, along such lines as colloidal characteristics, soil-moisture movement and availability, soil structure, chemical constitutents, and response to certain treatments and managements. The inherent productivity and the response to amendments of the individual soil types for specified crops will become current knowledge among agricultural workers. The extension of fundamental data and experience depend on classification of the soil on the basis of land units which may be given geographic extension. The study of plant adaptations will renew and continue interest in the biological sciences. Plant physiology, ecology, genetics, and pathology will be emphasized, as will colloidal chemistry and biochemistry.

Erosion Control

The problem of soil conservation is inevitably involved in any agricultural development. Breeding or introduction of a new crop may alter the balance of agriculture in wide areas. Its production may require new and, to the soil, hazardous methods of cultivation. It may open new regions to the plow. Thus the introduction and breeding of new drought-resistant varieties of wheat made profitable the cultivation of thousands of acres of western prairie land, with a resultant tremendous increase in the hazards of wind erosion during times of drought. New implements, new systems of cultivation, and new methods of processing, storing, and transporting crops may similarly alter the nature of agricultural production and its effect on the soil.

Except on the relatively small areas of perfectly flat land any form of agricultural development, however primitive, speeds up the process of erosion. There is ample evidence that erosion was an important factor in the destruction of primitive civilizations whose agriculture never progressed beyond the stage of the ox-drawn plow. But technological developments affecting the soil have not been all on the debit side. The same large tractors that turned the virgin sod have been used to build terraces to conserve the rainfall and the soil. Plant exploration and scientific plant breeding have discovered and developed plants that protect the soil as well as those that expose it. The same engineering skill that was used to drain the prairies of the upper Mississippi Valley now is used to build terraces, check-dams, and farm reservoirs.

In short, if technology has brought problems it has also brought knowledge and skill with which to help solve them. Technological development affecting agriculture, although it may have increased the rate at which new land has been affected by erosion, probably has not altered in the long run the fundamental effect of agricultural activity upon the soil. Perhaps there are a few exceptions to this statement. Large-scale lumbering, made possible by the use of machines and made profitable by our tremendous industrial development, probably has wrought irreparable damage to much forest land. But it is generally true that cultivated soil is exposed to the erosive forces of wind and water with substantially the same effect whether the cultivation is by ox-team or gang plow.

But pressure of necessity makes agriculture naturally an exploitive process. The spur of hunger and want stimulates production. Conservation develops when it becomes apparent that only on the basis of conservation can production be permanent.

The application of scientific methods to the study of soil erosion and its control is a recent development. Prior to 1929, when the first erosion experiment stations were established, a few pioneering State colleges and experiment stations had investigated the subject but most knowledge of it has been gained incidentally. The first understanding of the widespread incidence of erosion was gained by soil scientists engaged primarily in the survey and classification of soils. Foresters were investigating the importance of forest cover as a protection to the soil and the occurrence of disastrous soil washing as an aftermath of destructive lumbering practices and forest fire. A few exceptional farmers had taken adequate steps to prevent soil washing.

In the papers of both George Washington and Thomas Jefferson are letters to the managers of their estates urging such practices as the filling of gullies with brush and straw and plowing across the slope rather than up and down. In certain Pennsylvania communities strip-cropping and the leaving of grass waterways through cultivated fields are traditional farming practices—with readily apparent benefit to the soil.

The practice of building a system of hillside ditches or terraces in cultivated fields developed in the South more than half a century ago and has spread throughout most of the Southern States east of the Mississippi. Most of these early terraces were built without engineering knowledge, and without a full understanding of their limitations. As early as 1890, after an effort to improve the terraces then in use, Priestly Mangum, developed the now famous Mangum ter-

race. Even until comparatively recently, however, scientific study of soil conservation had not progressed far enough to prevent the widespread construction of terraces improperly designed to carry the run-off of the fields and improperly related to agronomic practices necessary to make them effective. Thousands of acres too steep and too erosible for any type of clean-tilled cultivation were terraced and planted to cotton.

As the first studies of the problem of soil were generally incidental to other research and were carried on by engineers or foresters or soil specialists, they were for the most part limited by the professional horizons of the men and agencies conducting them. To a large extent, we still have an engineer's, a forester's, an agronomist's, a soil specialist's approach to the problem of soil conservation.

As the scientific study of soil erosion progressed it became increasingly apparent that a syntheses of these divergent viewpoints was necessary. A technique of soil conservation was needed. Out of the knowledge of every scientific discipline which could contribute, from the technique of every agricultural profession which could be made to play a part, a coordinated plan of soil conservation is being built.

Since 1933, when the Soil Erosion Service (now the Soil Conservation Service of the U. S. Department of Agriculture) was established, there has been a tremendous expansion of work in soil conservation. New techniques have been developed and old ones tested and applied on a scale never before attempted. During the last 3 years great strides have been taken toward a synthesis of new points and plans. A coordinated attack on the problem of erosion has been developed and applied under a wide variety of conditions. It is bringing the resources of agronomy, forestry, engineering, and soil science together in a unified, integrated program of erosion control.

It is not too early to say that the concept, if not the final methods, of scientific soil conservation has been established, tested, and proved. This development of an integrated approach to the study and control of erosion is the most important technological advance in the field of soil conservation.

The essence of the coordinated plan of erosion control, as practiced by the Soil Conservation Service, is flexibility. The aim is to treat each farm and field in accordance with its individual needs and adaptabilities. Reliance has been placed on no single technique. Instead, the soil conservationist has utilized every available method in his program. Most of his actual technique can rightly be claimed as the development of some older agricultural profession. Strip-cropping, terracing, contour cultivation, range and pasture management, forestation, gully control, and many other practices have essential places in a coordinated erosion control program.

The significance of technologies which will provide economical and adequate conservation of soil cannot be easily overstated in terms of social advantage. The wastage of soil is wastage of the basic asset on which society depends.

VIII. CHEMICAL FERTILIZERS[10]

The cultivation of plants for sustenance dates from the remote past. In the course of ages, knowledge was gained fortuitously that the growth of vegetation was promoted by the addition to the soil of certain materials and that the continued raising of crops without such additions frequently resulted in decreased yields.

Although the Romans were aware of the social, economic, and political significance of such soil deterioration, little or nothing was known of the principles of fertilization until the early years of the nineteenth century. With the understanding of these principles came the birth of the fertilizer industry which at first dealt in naturally occurring materials and various animal and plant wastes, later supplemented by the byproducts of other industries. The modern chemical fertilizer industry began with the discovery in 1840 that the fertilizing value of bones was increased by their treatment with sulfuric acid and with the commercial application thereof for the production of dissolved bone and superphosphate.

Commercial mixed fertilizers are mixtures primarily of materials that contain the three fertilizing elements, nitrogen, phosphorus, and potassium. Until comparatively recent years, the United States was largely dependent upon foreign sources for its nitrogen and potassium and was self-sufficient only as regards phosphorus. Our enormous deposits of phosphate rock, which for years not only met our own demands for phosphorus for fertilizer purposes but also supplied those of many European nations, still suffice for all our anticipated needs in the near future. As a result of technological progress, a synthetic nitrogen industry, based on the utilization of the inexhaustible supply of the nitrogen of the air, has been developed, the capacity of which, together with our byproduct nitrogen capacity, is capable of expansion to supply all future needs, whether for fertilizers or explosives. The dearth of potassium during the period of the World War, resulting in a thousandfold rise in price, stimu-

[10] This section was prepared by A. R. Merz, Chemist, Bureau of Chemistry and Soils, U. S. Department of Agriculture.

lated a successful search for native deposits of potassium salts. The discovery of large natural beds of these salts, coupled with the development of procedures to exploit them, and other sources of potassium in this country, has freed us from dependence on foreign monopoly for this element also.

Supply Problem Arises

During the early years of the fertilizer industry the materials that were available to the fertilizer manufacturer for use in the production of commercial mixed fertilizers contained relatively little of the three elements considered of primary importance. The mixtures prepared from them were necessarily low in these elements. Low-grade materials, however, are characterized by high costs of transportation and handling relative to their plant-nutrient content. This disadvantage to their use resulted in a gradual increase in the concentration of many fertilizer materials that were already in use through improvements in methods of manufacture and the introduction of refining processes. With increasing consumption of commercial fertilizers and the resultant growth of the fertilizer industry, the more serious question of supply arose. A number of materials extensively used, such as cottonseed meal and tankage, were more and more diverted to use as feed for stock. In addition, the output of the industrial byproducts that found use in the fertilizer industry was dependent on the sale of the principal products and could not be increased independently to meet increased demands for the byproducts. The increased demands for fertilizer materials have therefore been supplied more and more by high-grade chemical products.

A corresponding increase in the concentration of the mixed fertilizers did not occur. The primary reason is the fact that the various grades of mixed fertilizers had become established when low-grade materials only were available and farmers continued through conservatism to demand these grades. Fertilizer manufacturers were compelled, as they gradually substituted higher grade for lower grade materials in the preparation of their mixtures, to use increasing quantities of inert materials or fillers to obtain the grades demanded. The chief causes for such rise as has taken place were (1) efforts of the manufacturer to sell higher grade fertilizer mixtures rather than to add increasing quantities of filler to his mixtures, (2) the educational campaign of agronomists and other officials of various agricultural experiment stations and of the United States Department of Agriculture to bring to the attention of farmers the savings accruing in the purchase of higher grade fertilizer mixtures and (3) the passage of laws in a number of States prohibiting the sale of fertilizers containing less than a minimum quantity of plant nutrients, a result of the efforts of the same officials. Nevertheless, mixtures containing double the content of nitrogen, phosphorus, and potassium in the fertilizer mixtures ordinarily sold can be readily prepared by the use of materials that have been made commercially available. Also, to meet the former objection that fertilizer distributors could not apply uniformly in the field the lesser quantities of such higher analysis fertilizers that would be required to supply the same quantities of plant nutrients, distributors have been devised capable of uniformly applying as little as 50 pounds of fertilizer per acre.

More Reliance on Chemistry

Failures to obtain favorable responses on some soils when mixtures of only nitrogen, phosphorus, and potassium are used have brought forcibly to attention the fact that plants require for their growth other elements also and that certain soils may be so deficient in one or more of these "minor plant foods" as to limit the size of the crop obtainable. As the fertilizer industry of the future relies more and more for its supplies of fertilizer materials upon products manufactured by chemical processes, increasing consideration will have to be paid to providing the secondary fertilizing elements in mixed fertilizers. This will have an influence in limiting the ultimate concentration of higher analysis fertilizers as regards the primary fertilizing elements. Although most fertilizers of the present day supply more calcium and sulphur than are needed on the majority of soils, large areas of our lighter soils would, within a comparatively short time, develop calcium and sulphur deficiencies if these elements were omitted from fertilizers. The addition of compounds of magnesium and manganese to fertilizer mixtures has already become quite extensive. Recent experiments have shown that the application of small quantities of other elements such as copper, zinc, and boron to certain soils considerably increases the crop yields thereon.

In consequence of the growing use of synthetic ammonia and ammonium compounds in fertilizers, attention has also been directed of late to the fact that fertilizer mixtures containing nitrogen in such forms only tend to make soils more acid in reaction and that continued application thereof finally causes the soil acidity to reach a point that affects growth of crops adversely. A method of calculation has been developed for determining the potential acidic or basic reaction of fertilizer materials. By use of the values thus obtained, fertilizer manufacturers can know in advance the potential reactions of their various fertilizer mixtures. Extensive progress has been made toward the production of mixtures that are non-acid-

forming, particularly by the use of ground dolomitic limestone. The increasing necessity for use of neutralizing agents as well as need for provision of secondary plant-nutrient elements are factors that will probably limit the ultimate concentration of fertilizer mixtures as regards the three primary elements to the double-strength mixtures. Such mixtures, so adjusted as regards potential acidity or basicity and containing the secondary fertilizing elements best adapted to the particular soil and crop for which they are intended, will probably constitute the greater proportion of the fertilizer mixtures of the future.

Techniques of Application

Recent work has shown that the maximum benefits obtainable from the use of fertilizers are frequently not attained because of improper methods of application. Proper placing of fertilizers with respect to the seed both as regards closeness and relative location has been found to considerably enhance the increased yields. Too close proximity of a fertilizer to the seed is usually the sole cause of delayed germination, or even failure to germinate, as well as of injury to the young plants. The usual method of mixing the fertilizer with the soil in the row, practiced in many localities, is frequently a poor one. Methods of application best adapted to the different types of soils and kinds of crops are being gradually learned, and the knowledge thus acquired is being used for the designing of new fertilizer distributors and attachments, the increasing use of which is certain to enhance the average yields now obtained per acre with the use of fertilizers.

Prevention of the segregation of the materials contained in mixed fertilizers that occur during the handling processes between the fertilizer factory and final lodgement in the soil is receiving attention. The extent to which this segregation takes place increases with differences in the sizes and specific gravities of the individual particles of the materials used to prepare the mixtures. As a result of segregation the composition of the mixture ceases to be uniform throughout so that, when the mixture is applied in the field, the same relative quantities of the different fertilizing elements do not become accessible to the roots of the individual plants. In consequence, a given plant may have at its disposal more of one of the fertilizing elements than it requires while it is not supplied with enough of another element for its full development. Methods of granulation have recently been devised which not only prevent segregation but also reduce the tendency of the mixtures to cake or become sticky and facilitate the process of their distribution to the soil.

Developments and improvements of fertilizers in the future have many important possibilities. Nationally, we have become self-contained as regards the elements on which we are dependent for the production of our future crops. As a result of new and cheaper methods of manufacture, the cost of these elements in fertilizer materials has been considerably reduced. Further savings are possible by using these fertilizer materials for the production of double-strength fertilizers. The employment of such double-strength mixtures, granulated, properly placed, and suitably adapted in composition to the soils and crops to which they are to be applied, will considerably increase crop yields per acre per unit of fertilizing element employed. The use of fertilizers will thus be made more profitable and their more general employment and in larger quantities per acre will result. The increased yields per acre obtained will encourage the withdrawal of lands now unsuited to cultivation and their sowing to grasses or their reforestation, and an intensification of the cultivation of the better suited lands with greater consideration given to the conservation of their fertility. In many farming sections the development and maintenance of pastures on the poorer land, with the aid of fertilizers, and cultivation of only a small portion of the land, will necessitate the expenditure of less labor on the part of the farmers in proportion to the financial returns.

IX. MARKETING PRODUCTS[11]

Within virtually the space of a lifetime we have changed from an agricultural to an urban-industrial Nation. This transformation has necessarily revolutionized the methods of marketing farm products in the United States. No longer face to face on market days the farmers and consumers see most products pass through many channels and processes between the farm and the home. The next lifetime seems destined to witness the improvement, adaptation, and extension of the techniques and equipment now at work rather than any dramatic change.

Development of Vast Marketing Machinery

Development of different kinds of market places is one of the outstanding advances. The kinds of markets have changed with changing years, but many of the earliest American markets still exist. Our present market places range from small uncovered local curb markets, through the large city or municipal markets

[11] This section was prepared by Caroline B. Sherman, Associate Agricultural Economist, and Carl H. Robinson, in charge Division of Cotton Marketing, Bureau of Agricultural Economics, U. S. Department of Agriculture.

of earlier days, to the newer great terminal markets and outlying regional markets for receiving and redistributing motortruck receipts. Ownership may be public or private. Methods, technical equipment, regulations, and authority vary with the markets—from the antiquated to the most modern. Then there are the exchanges and the auctions. Branch and chain stores with their accompanying problems are among the newer developments.

Methods of marketing or shipping from the farm vary correspondingly. A relatively few farmers still market direct by wagon, motorcar, or motortruck. Others still act as their own salesmen on the local market. Others sell from roadside stands or by parcel post. The old personal relationships between the consumers and those who supply their wants die hard.

A large and increasing number sell through intermediaries of many kinds. Some find the methods involved in such selling satisfactory and some do not. Most farmers feel that the complicated systems are necessitated by modern conditions and demands. They may deplore the mechanized and commercialized methods but they expect an increasing proportion of the farm commodities to be marketed through these channels. They want the channels kept clear and open, they want them improved, and to a certain extent they want them regulated.

Service to Improve Entire Marketing Machinery

Federal and State agencies have been working to those ends actively since 1914, when a wave of interest in costs of living and costs of distribution reached a crest. Subsequent improvements in the marketing mechanism include the Nation-wide system of standards for practically all farm products, formulated by the Bureau of Agricultural Economics and now widely used, the shipping point and market inspection service, the Nation-wide market news service on farm products, the agricultural outlook service, and educational regulatory services, both State and National, that tend to improve the ethics and the technique of marketing.

Techniques involved in these services are many, varied, and ingenious. Each service could tell a technological story in itself. In each case the service, soon after being inaugurated, has become virtually an indispensable part of our vast marketing machinery.

Transportation and refrigeration, among the chief technological advances that have aided this revolution, are treated elsewhere in this report. The importance of their part in past, present, and future could scarcely be overemphasized. Among recent notable transportation developments in marketing is the use of the motortruck. Marketing advantages and disadvantages attend its growing use. Direct buying of hogs, a vexing and unsettling question, is an example of the attendant developments.

At present the most rapid technological changes and advances in marketing practice are found in the field of freezing and refrigeration. With adequate refrigeration available to a rapidly increasing number of households the use of frozen products will expand rapidly. The subdivided refrigerator car is coming into use. The three box-like containers on one flatcar can be placed on three separate trucks and sent to small towns or dealers not readily reached by railroads or not needing full carlots, or to summer resorts. Railroads are being asked to provide for re-top-icing in transit. Presumably this means reduction in rate of melting and consumption of ice. In sort, we may be passing out of the "glacial period" of marketing.

There are obvious advantages in preparing a frozen product in consumer packages. Frozen products are not to be regraded or resorted. There are different grades of the product and they will probably be stated on the package.

Progress in the development of canning of foods has been marked and there is now a promising tendency toward informative labeling of canned goods. The marketing of carefully graded and accurately branded frozen foods may accelerate this tendency in the canned goods industry.

Farmer Cooperation in Marketing

Besides the farmers who sell direct and the farmers who sell through middlemen, we have the cooperative marketing of farm products by groups of farmers. Cooperative marketing in this country has reached huge proportions. These cooperative organizations vary from simple associations to large and complicated bodies employing most of the techniques of the usual commercial marketing but employing them for the benefit of the farmer members.

The cooperative marketing idea now seeks primarily to eliminate certain so-called wastes in the marketing process. The principal difference between the chain-store idea and the farmers' cooperative today is the direction of integration. The chain-store integration proceeds from the consumer back to the producer while the cooperative-marketing scheme integrates from the producer forward to the consumer.

It is impracticable in a short space to examine these two methods and appraise their effectiveness. Both have had influence in changing the marketing of farm products during the last 20 years, and upon the elimination of some physical waste and unnecessary costs in the process. Their future relative strength will depend largely upon their relative services to society as a whole.

Technological Improvements in Marketing and Distribution

Technological improvements in marketing have aided farmers in disposing of their products and consumers in obtaining food and fibers that more nearly fit their wishes and pocketbooks. Most of them probably were designed to more nearly satisfy the consumers' requirements. Many have lowered or will lower the costs of both food and clothing. Some have added to living costs. Many, but not all, are socially desirable. Nearly all have arisen out of or are related to the growing complexities of our American life.

Some of the specific techniques developed in channels of marketing and distribution may be illustrated in a discussion of technical developments in the marketing of cotton. In this respect cotton is perhaps classic. For the sake of brevity this discussion will be restricted chiefly to developments in which the United States Department of Agriculture has had a part. The developments occurring within the limits of a short lifetime will be discussed, principally.

Parts of other sections, especially the one on dairying, touch on other marketing improvements and changes. In general the techinques developed in marketing and distribution channels for cotton, as well as for other farm commodities, include the following: (1) Improved techniques in methods of harvesting and preparing products for market which may conserve labor, improve quality, and lower costs; (2) use of uniform standards to facilitate grading and expedite distribution of various qualities of products through the numerous channels from producer to consumer; (3) provision for and improvements in existing techniques of grading, inspection, and regulation of the distribution of most important farm products; (4) standardization and the development of new types of containers for products moving through marketing channels—in some instances with standards for different containers for farmers, wholesalers, and retailers; (5) improvement of business and accounting systems all along the line, and (6) developing and designing new uses for agricultural products.

Farmers Adopt New Techniques Slowly

Mechanical inventions usually require years of trial before their general acceptance and use. The same is true of new techniques in marketing and distribution. In cotton marketing, as in cotton production and manufacturing, new and old techniques may be observed in use side by side. The one-horse plow and the tractor may be seen in adjacent cotton fields in the Southeastern States. Cotton is still sold in the seed in some local markets, with only the most general reference to quality in pricing, but across the street, at the same time, in the same market, farmers may be selling lint cotton in bales, on the basis of accurate quality classification and receiving payment on the basis of central-market premiums and discounts for quality. One-horse wagons and up-to-date trucks are both used to transport cotton to the same local markets in the Cotton Belt. Likewise in cotton manufacturing it is not unusual to see equipment of the latest design cleaning, spinning, winding, and weaving in a mill which also has machinery bought 40 years ago performing similar functions. Perhaps new techniques are adopted too slowly, but care in adoption of the new is often economically and socially desirable.

The basis for a much more nearly perfect marketing mechanism for cotton is gradually being built, but there have been no quick changes, nor are they likely to occur. The development of techniques and information is always considerably in advance of their general utilization by farmers for whom they are primarily designed. For example, it is now possible for most farmers to be much more fully informed relative to the supply and demand conditions for cotton than formerly and at little or no cost to the individual. It is possible for a great many more farmers to plant improved varieties of cotton than actually do plant such varieties. Facilities are available for supplying information on the quality of more cotton before it leaves the farmers' hands than is actually classified.

Resistance to change on the part of both farmers and cotton buyers is perhaps the greatest obstacle to be overcome. The resistance of one group may have a different base from that of the other, but both frequently react against farmers and sometimes against buyers. This lack of complete effectiveness is perhaps due in part to a lack of facilities to demonstrate effectively the advantages of using new techniques and the results of the development of new techniques, such as information on varieties, quality, and supply and demand conditions for cotton.

Farmers Confronted with Many Technical Questions

Beginning at the farm on or before planting time, farmers are confronted with such technical questions as the following: How much of the various qualities of cotton should be produced to obtain the largest net income? Where can seed of tested cotton varieties be obtained, possessing fairly stable known qualities for planting, such as those developed through years of technological experimentation and technical research by State and Federal agencies? How many times should cotton be plowed, hoed, and picked, so as to obtain a maximum net income? What type of cotton gin should be patronized? Should cotton be sold in the seed or in the lint? How can the quality of lint cotton be accurately ascertained? When is the

most advantageous time to sell? Many of these questions obviously must be answered by the individual farmer.

The marketing mechanism—which is so closely related to the economics of production that the technological phases of the two cannot be separated—can undoubtedly be improved a great deal more in the years to come. The foundation for much of the work in improving cotton marketing and decreasing distribution costs has been well laid.

For example, through such technical developments as the crop meter (a device attached to an automobile that is driven along the highway to register the extent of a "sample" area planted to cotton) the accuracy of crop estimating has been increased. This, of course, is a mere detail in the recent improvements in the techniques of the elaborate governmental system of crop estimating, reporting, and forecasting. Improvements in this work have made it possible for most farmers to obtain the information regarding supplies of cotton comparable to that possessed by the largest commercial concerns. Estimates are also made of the quality of cotton carried over each year and of that ginned during each season and some individual farmers have been furnished with information regarding the grade and staple length of each bale of their cotton. Other similar information is available but the accuracy and comprehensiveness of such data are being improved yearly. Plans are continually being devised to improve the techniques of distribution for various kinds of information needed by farmers and as a corollary to these changes will go a type of information that will more nearly fit local needs.

Quality is a basic factor affecting demand and through the development of a wealth of techniques and devices our investigators are learning much more about the character as well as the grade and staple of cotton than had been previously known. This work is basic to improvements in the accuracy of quality measurements and to necessary revisions in standards for the grade and staple of American cotton. Along with improvements in the standards for quality and in classing will go changes in the techniques of supervision and instruction for qualified cotton classers, so that the accuracy of this work will be further improved. It is not improbable that the techniques developed in the field of quality measurement and practical grading and classing will eventually lead to an accurate classification of the entire cotton crop before it is sold by growers. As an additional definite practical step, an identification device was recently invented which may make it possible to maintain the identity of cotton bales in marketing channels. The general adoption and use of such a device would facilitate the use throughout the marketing chain of an initial classification of the cotton and would tend to simplify marketing procedures.

Official Standards for American Cotton

Because of the many improvements in the cotton-marketing system that may be visualized but have not yet been adopted too much emphasis can easily be placed upon probable future developments. Outstanding among the technical developments that are now in general use are the standards for American-grown cotton, promulgated by the United States Department of Agriculture. These standards are represented by practical forms for both grade and staple. As a result of the suitability and reliability of these standards, the world buys American-grown cotton largely upon American standards, which have thus become the universal standards for the grade of American cotton. The reliability of these standards has meant economic savings within the field of distribution and has aided in stabilizing and reducing the complexity of marketing machinery and made possible more accurate price quotations for cotton.

Cotton-Drying Machinery Developed

Improvements in the technique of preparing cotton for market are expected. For example, new drying machinery has been developed for the drying of seed cotton before ginning. Ginning techniques are being improved in many ways. Increasingly precise and scientific knowledge of fibers made possible by ingenious methods and devices is helping. The actual machinery of the gins, the methods of using it, and the factors that make for success, are being studied in an experimental gin plant and laboratory built for these purposes. Attention of the research staff has been focused principally upon those problems of great concern to the cotton grower and ginner, such as the influence on ginning (1) of seed cottons of different staple lengths, moisture contents, and seed characteristics; (2) of different methods of harvesting and different periods of picking; (3) of varying degrees of cleaning and extracting; and (4) of saw speeds, seed-roll densities, and number and design of saw teeth. Results obtained in this work are going into commercial practice with resultant economic savings.

Cotton Utilization

Efficient disposal of the cotton crop as a whole is dependent in part upon a comprehensive understanding of the techniques of utilization. Moreover, expansion of markets for cotton through the development of new uses is dependent upon adequate technological and economic information regarding the uses for cotton. The paucity of information on the technology

and economics of cotton utilization is evident in the literature of cotton marketing.

For example, the effect of long-draft spinning upon the qualitative requirements of cotton mills that spin various kinds of yarn is as yet not fully understood, although cotton mills have been installing this type of machinery for about 15 years. It is known that long-draft spinning is probably the most important technical development that has taken place in the cotton-textile industry during recent years, from the standpoint of cost reduction. A complete understanding of the effect of changes in staple length and grade, upon the cost and quality of finished cotton goods, is lacking, from both a technological and an economic point of view. Such information is basic to a quality-improvement program for American cotton and more must be known about qualitative requirements in the future.

More is known about quantitative requirements for cotton than about qualitative requirements. Techniques for obtaining information regarding the amount of cotton used for various purposes have been developed. This information has been helpful in developing techniques designed to widen the uses and thus the markets for cotton. The main objective of this work is to develop cotton materials that are better suited for various uses than the products now in use and thus increase the uses for cotton. Cognizance is taken of the fact that wool and other textile materials are better suited than cotton products in certain uses and that unless a more suitable or a cheaper cotton material of equal quality is available cotton will not be used in these instances. It would be uneconomical and socially undesirable to use cotton in such instances.

Included among the new materials developed was a cotton airplane fabric, during the World War. More recently the United States Department of Agriculture has designed and directed the manufacture of open-mesh cotton bags for packaging fruits, nuts, and similar products. A cotton material that is suitable for bagging for cotton and that would be economical in some years, if net-weight trading—which seems economically desirable and probably will eventually be generally practiced—were adopted, has been developed. The most recent development is a cotton fabric for reenforcing bituminous-surfaced roads, which may make possible the maintenance of improved country roads at a lower cost.

The passage of the Federal Warehouse Act of 1916 marked the beginning of vast improvements and modernization of warehouses, equipment, and techniques. The warehouse receipt has become a universally accepted collateral for loans. Insurance rates have been reduced. Accounting methods have been improved. Mechanical means for cheaper and more efficient handling of cotton have been developed. Weather damage to cotton has been reduced. Virtually all of these improved techniques have resulted in lower marketing costs for cotton in transit from the farm to the ultimate users.

No discussion of technological progress in cotton marketing and distribution would be complete without some mention of cottonseed. In a little over 60 years cottonseed has been converted from a very troublesome waste into one of the major cash crops of the South. The growth of the commercial utilization of cottonseed has resulted principally from the technological improvements ranging from the discovery, in 1879, that cottonseed oil could be purified for human consumption to the promulgation of official standards for grading, sampling, and analyzing of cottonseed sold for crushing by the United States Department of Agriculture in 1932. These standards are widely used and it seems probable that in the future much of the technical progress in the marketing and distribution of cottonseed will come through improvements in the extent and techniques of grading. These should result in stabilizing marketing practices, narrowing the price spread between producer and consumer, and payment to individual farmers on the basis of the quality of their product.

Lower Costs and Higher Living Standards

Most of the work that the United States Department of Agriculture has undertaken in connection with cotton marketing has been aimed directly or indirectly at lowering the price spread between producer and consumer. Both the cotton farmer and the cotton consumer have benefited and probably will benefit from most of this work. Not all of it has yielded immediate tangible results. Ultimately the savings from a more efficient marketing system will be reflected in part in higher returns to growers and in part in lower costs to consumers. The standard of living of people generally should thus be raised. Our techniques for measuring the extent to which each group benefits have often lagged behind tangible advances in marketing techniques, such as the promulgation and practical use of standards for the grade and staple of cotton.

Crisis Met With a Social Invention

The crisis in cotton marketing brought about by declining world prices for cotton and excessive stocks and other developments associated with the economic depression was met by techniques revolutionary in character. The story of the Agricultural Adjustment program in all of its ramifications and endeavors as related to cotton is a chapter in economic and agricultural history that is yet to be written in its entirety. The Triple A is a social mechanism that may be subject to

as much improvement as was the first cotton gin. It or some other means for securing more equitable incomes for cotton farmers and conserving the agricultural resources of the South was long overdue. Social inventions such as this have been implemented by techniques previously developed through marketing research and it is probable that the continuation of the Triple A may facilitate the use of other techniques now in the process of development by market research workers in the United States Department of Agriculture and elsewhere.

Looking ahead along the tangled and complex paths through which our farm products are marketed, whether for food or for textiles, we see the problem of letting in the light, of straightening out and clearing channels, as receiving chief attention. Effort will be designed to help both farmers and consumers. The two aims are not incompatible. As our marketing program deals with the materials for the food and clothing of this and other nations, perhaps in no other line of work is it more necessary that the technician and the social inventor work hand in hand.

X. INDUSTRIAL UTILIZATION OF FARM PRODUCTS[12]

There are a number of possibilities for the extension of present uses of agricultural products in industry, but before these can be properly evaluated consideration must be given to present industrial trends which might have a limiting effect on such expansion.

Synthetic Products

Acetic Acid, Acetone, Ethyl-Alcohol.—Acetic acid is produced by the fermentation of the natural sugar extracted from plants, and may be also made by hydrolyzing the starch or cellulose content of the plant into sugar. When sugar is fermented by yeast, ethyl alcohol and carbon dioxide gas are produced, and the alcohol can then be oxidized to acetic acid by the further fermentative action of vinegar bacteria. Acetic or other acids may also be produced directly from cellulose by employing special bacteria. The acetic acid in turn will produce acetone by suitable chemical or bacterial treatment. To produce these same compounds by chemical synthesis, lime and carbon are combined to produce calcium carbide which yields acetylene by reaction with water. Acetylene can then be converted into acetaldehyde, acetic acid, and acetone under proper catalytic conditions. At present, this process constitutes an outlet for the waste products of the carbide industry, but by expansion the fermentatively produced products might be entirely supplanted, since the cost of the synthetic product is low. Acetic acid is also produced by the destructive distillation of wood, by which process methanol (wood alcohol) and formaldehyde are also produced.

Methanol and Formaldehyde.—Methanol and formaldehyde result from the pyrolytic decomposition of any cellulosic material and therefore can also be produced from farm waste products such as oat hulls, corncobs, nutshells, and fruit pits, although at present the commercial destructive distillation products are mainly produced by wood distillation. However, methanol is also commercially synthesized by combining carbon monoxide with hydrogen gas under pressure in the presence of a catalyst. Formaldehyde is an oxidation product of methanol. Because of its low cost, the present synthetic methanol has practically driven the destructive distillation product from the market, except in certain limited fields, such as denaturation of industrial alcohol.

Ethyl, Isopropyl, Butyl, and Amyl Alcohols.—By changing the conditions of the pressure catalytic process, or by changing the kind or percentage of the raw gases used, higher alcohols may be produced, such as ethyl (or grain), isopropyl, butyl, and amyl alcohols. Such alcohols may also be produced from the olefines present in natural gas or in the distillation gases from the petroleum refining industry. Industrial plants have already functioned successfully in producing ethyl alcohol from both of these sources. Ethyl alcohol may also be produced from wood by hydrolysis of the cellulose of the wood into sugar and subsequent fermentation. Several plants have already been erected in which chipped wood is treated with mineral acids and the resulting product is either used directly as a stock food or is fermented into alcohol.

Rubber.—Commercial rubber has been produced heretofore from the sap of the rubber tree. However, not only are rubbers producible from what are now considered weed plants (golden rod, milkweed, etc.), but recently a synthetic product has been produced from acetylene gas, which is further synthesized into a product known as chloroprene rubber. Other synthetic rubberlike compounds are being made.

Resins and Plastics.—Our present civilization is making increasing use of artificial resins and plastic compositions. Resins of the bakelite type are combinations of aldehydes and phenols. Aldehydes are produced by fermentation of carbohydrates, by chemical or bacterial oxidation of alcohols, and by destructive distillation of cellulosic products. Phenols are also

[12] This section was prepared by P. Burke Jacobs, Senior Chemical Engineer, in charge Agricultural Byproducts Laboratory, Bureau of Chemistry and Soils, U. S. Department of Agriculture.

produced, to some extent, by the destructive distillation process. But phenol can also be produced from coal, and aldehyde from acetylene gas. Furfural is a special aldehyde which is being produced from the pentosan content of agricultural wastes by distillation with mineral acid. Plastics are also made from the casein recovered from skim milk, from the proteins of the soybean and other oil seeds. Other plastic resins are synthesized from urea.

Other Synthetic Products.—The substitution of artificial coal-tar dyes for indigo and other natural vegetable dyes is a classic example of modern synthetic organic chemicals displacing natural products. Synthetic processes might conceivably be used to produce fats, carbohydrates, vitamins, and hormones. Such processes are seriously foreshadowed by the results of laboratory experimentation but are not economical as yet. It seems doubtful whether sugar, starch, or complex fats suitable for food can be produced synthetically at a cost to compete with the natural products. In the case of vitamins, there is some possibility that commercial synthesis may be accomplished. Various organic drugs have been produced without resorting to plant life for the original material.

Oil paints and varnishes depend for their protective power on the formation during the drying stage of an oxidized film that is hard and somewhat resinous in character. Vegetable oils are classified as "drying" or "semidrying", depending on the rapidity or completeness with which they dry by absorption of oxygen. The relatively cheaper petroleum oils do not have this drying or oxygen-absorbing property, but with modern synthetic methods compounds have been produced from petroleum which have some drying properties.

From these examples it is evident that the supplanting of farm products by nonagricultural products, as industrial raw materials, is already well under way in certain lines. There is, too, a possibility that uncultivated agricultural products will become raw materials to compete with farm products. The use of wood waste at very low cost adversely affects the possible utilization of crop wastes.

Increasing Utilization of Farm Products

In expanding the use of agricultural surpluses in nonfood industries, certain trends are under way which may result in greatly increased consumption.

Cellulose Products.—We live in a cellulose age. Heretofore cellulose has been used mainly in the form of lumber (wood), paper, cotton, and linen. Tremendous quantities of cellulosic wastes are destroyed annually as crop byproducts, which are suitable for producing synthetic lumber, insulating board, paper, absorbent paper products, and cellulose derivatives, such as rayon, lacquer, etc. The enormous consumption of cellulose by the paper industry continues to increase. The young industries of synthetic lumber and construction insulation board have established places for themselves in our economic life. Delayed somewhat by our general economic conditions they are again demanding increasing amounts of cellulose. The world rayon output during the last 10 years has increased fivefold, and although today the production exceeds 1 billion pounds annually the increase continues. For example, the increase in the rayon production in 1935 nearly equaled the total world production 10 years ago. The rayon staple fiber production today only equals the rayon yarn production of 12 years ago, but this production increased almost threefold in 1935. Staple fiber is made into a distinctive separate textile which is becoming very popular. Rayon staple fiber, cellulose plastics, and some of the lacquers are yearly demanding increasingly large amounts of industrial alpha-cellulose. The shoe industry through new innovations in its processes is demanding large amounts in special grades of industrial cellulose. In producing 1 ton of cane sugar, about 1 ton of sugarcane bagasse is also produced. This waste has until recent years been used as a fuel in the sugar factories. Now the fiber board industry uses large amounts of this waste, as well as some cornstalks and straw. It is easily possible to go far beyond the present styles of boards produced and enter other fields of building material not at present competitively attacked. The use of wood waste for producing fiberboard can be supplanted by the use of cornstalks or straw, should competitive prices permit. A large variety of pressed products can be produced from such materials as straw, cornstalks, and sorghum cane waste, and several plants are already in operation. By further refining, many grades of paper can also be produced from these materials, and by still further chemical treatment it is possible to make cellulose derivatives from which textiles, plastics, lacquers, films, cements, and explosives may be produced. More than a hundred million tons of cellulosic material are produced and wasted annually as byproducts of our grain crops. Seed flax straw, for instance, a byproduct of the linseed-oil industry now largely wasted, can be processed to yield paper or fiber for textiles.

By processing certain vegetable oils, such as linseed, soybean, and tung oils, many new industrial products having special properties might be evolved. The new synthetic casein wool fiber ("lanital") made in Italy is based on the casein obtainable from that Nation's supply of skim milk. Soybean protein might possibly be substituted for the skim milk casein. A pound of coagulated skim milk is needed for a pound of this yarn. Present production capacity is stated to be 11,000 pounds a day. Comparable production in

this country would consume substantial amounts of soybean and skim milk casein. New oils can be recovered from grape and tomato seeds, nut shells, and fruit pits. By hydrolyzing cellulose certain adhesives are theoretically possible. The present production of furfural from oat hulls might be greatly expanded and other crop wastes might be used as a source of supply. At present, furfural has been used for decolorizing wood rosin, for producing plastics, and for treating lubricating oils used in internal combustion engines. Furfural, however, forms the basis for a number of synthetic chemical reactions whereby dyes, perfumes, and other compounds are evolved.

Furfural exhibits antiknock and antioxidant properties when added to motor gasoline and might be used alone as a motor fuel. It has been used to stabilize petroleum oils and as an ingredient of embalming fluids. The principal objection to its use in many lines of work lies in the fact that its compounds are dark colored. If this coloration difficulty could be obviated a large field of uses would be opened. It is from the petroleum industry that the new increase in the demand for furfural has come. It has proved very successful in the purification of petroleum oils and the needs of this giant industry are such that the demand for this compound has been materially increased.

The use of ground materials such as cobs and nut shells to produce substitutes for wood flour may be greatly expanded. Large volumes of wood flour are used in the explosive industry as a diluent and in the molded plastic industry as a filler. Much of this wood flour is imported and sells at a price that invites competition from processors of cellulosic farm waste. Experimental work has failed to show that flour from these wastes will not meet the specifications upon which wood flour is purchased. Incidental to the use of the cortex fiber of cornstalks for paper or other purposes, pith may be obtained as a byproduct which will find use as an insulation material and absorbent for nitroglycerine for the manufacture of dynamite. The possible future growing of the Jerusalem artichoke for the production of a sugar known as levulose, from the tubers, would probably involve necessarily the utilization of the tops for paper or board manufacture and would result in the production of a considerable quantity of certain crop byproduct pith having unusual properties.

By hydrolizing cellulose wastes with acid and fermenting with special micro-organisms, alcohols, organic acids, and useful gases are obtainable which may find application in industry. By destructive distillation of certain crop by-products, acetic acid, methanol, tars, and activated carbons can be produced. Such activated carbons may be used for decolorizing oils, deodorizing, purifying of municipal water supplies, recovery of vaporized organic solvents, etc. From the tars, creosols, and oils having marked insecticidal properties can be recovered. From pecan shells a tanning extract might be recovered, and ground corn cobs might possibly be used to replace spent tan bark in the manufacture of white lead. Cobs, hulls, and other crop wastes, as well as the charcoal resulting from their destructive distillation, may be pressed to form fuel briquettes for farm use. Cellulose pulp might be pressed into shapes such as window frames and chair seats, replacing other industrial materials, or used in conjunction with other materials to secure lightness and porosity. Vegetable oils may be treated to increase their lubricating value for special purposes, especially in internal combustion engines.

By fermentation, alcohols or special compounds may be evolved from pulp-mill wastes or from the byproducts of the constarch industry, from which also lactic and acetic acids are possible resulting products. Oxalic acid can be produced from corn cobs or oat hulls. Xylose, a nonfood sugar of unknown value, can be produced from cottonseed hulls or similar wastes. Insulating material might be produced from feathers or, by suitable treatment, feathers possibly could be converted into artificial silk. Cellulose fibers may be substituted for rock wool or other mineral insulation. The further use of casein for new resins and plastics is possible. In addition, the incidental recovery of lignin in the processing of cellulosic wastes may result in new industrial uses of this product, which is now entirely wasted. and yet which constitutes 30 to 40 percent of the original material. From the alcohols and organic acids derived from agricultural products various solvent esters may be produced.

Alcohol may be used as fuel for automobile engines to compensate for a diminishing petroleum supply. This would provide an enormous outlet for farm crops and byproducts high in fermentable matter. On the basis of present crop production the normal surplus of corn would supply only a small quantity of the alcohol required for even a 10-percent blend with gasoline. At present, alcohol costs approximately five times as much as gasoline, and even with an increasing gasoline price the cost of alcohol must be further reduced, entailing the use of cheaper raw material as well as new economies in methods of production.

Rubber is almost entirely imported. The production of satisfactory rubbers from domestic plants which could be grown as new annual crops might affect the agricultural situation. There is also some possibility of synthesizing rubber from the forest product turpentine.

Naval stores, so-called, are usually not considered to be farm products, but their production is a factor in

certain southern rural areas. Heretofore, the main use of turpentine has been as a paint and varnish thinner, but with the increased use of petroleum thinners and the decided swing toward lacquers in recent years the turpentine market has suffered. Turpentine is an excellent solvent and it is probably the cheapest available essential oil. It has certain peculiar chemical properties which make it eminently suitable for certain uses. One can visualize a future development in the naval-stores industry whereby the commercial mixture now known as turpentine will be fractionated into its components such as alpha- and beta-pinene, limonene, and dipentene, which will find enlarged markets for solvent or other purposes. Furfural is now used in decolorizing the rosin resulting as a byproduct from the solvent-extracted wood-turpentine industry. This furfural is largely recovered, but some possible new adaptations possibly in combination with turpentine constituents, might be visualized.

There is a possibility of using either agricultural or nonagricultural raw materials, interchangeably for producing the same or similar derived products. Any prognostications are subject to the prevailing economic situation, to the relative obtaining prices of raw and finished materials, and to the existence of other competing raw materials.

XI. TRENDS IN FORESTRY[13]

Federal properties are but a part of all those wild lands which constitute more than 60 percent of the area of the continental United States. This huge empire is sparsely populated. Though much of it has been exploited and abused, it still contains vast forests to which we must look for present and future timber needs. It grows forage, harbors much of our remaining wildlife, furnishes outdoor recreation for millions of people each year; and its forest and other cover help protect little waters which later flow through industrial centers and fertile fields. So existing and potential values of this wild-land empire are enormous.

Applied to this huge area, and with the impetus given by the current interest, many technologies being developed in regard to the national forests promise to have a profound effect upon other public and private forests and upon the social structure of the entire Nation.

Forest Influences

Nature created forests, spacing them strategically on watersheds throughout the country, where they served in part as huge sponges for absorbing rainfall and maintaining the soil and water supply. Similarly, nature clothed mountain slopes and hillsides, valleys, and plains with grass and other herbaceous vegetation which helped percolate precipitation into the soil. But man has disturbed nature's balance.

Without trees, shrubs, grass, and allied cover as deterrents, precipitation forms ever-growing little waters; rivers rush to the sea from their sources on exploited watersheds. This action, plus that of winds, leaves soil erosion and calamity behind. Specialists tell us that the dust storm of May 1934 swept 300 million tons of fertile topsoil off the great wheat plains; that 400 million tons of remaining material are washed annually into the Gulf of Mexico by the Mississippi; that generally water and wind erosion together each year remove beyond use 3 billion tons of soil.

Numerous measurements and tests are being made throughout the United States. Immense amounts of data have been collected and analyzed. Values of forest, range, and other vegetative cover in flood prevention and soil absorptivity have been established.

But technologies are as yet in the preliminary stages. They must be further developed and refined, and applied Nation-wide. For social significances of preventing floods and erosion and regulating streamflow by means of vegetative control are broad and far reaching. They impinge upon agriculture and industry alike. The present and future of communities such as those of southern California are directly linked with proper water conservation and use.

Technologies of Multiple Use

There are several methods by which the national forests and their many resources, including water, forage, wildlife, and recreation as well as forests, might be conserved through management. One is by locking them up—conservation through abstention from use. Another is by permitting one planned use or type of use, in effect locking up most of their resources. This is the tendency on wild lands in private ownership. Under either of these two methods most of our renewable resources and the lands themselves must inevitably be under utilized. Yet nature's gifts are the basis of all economic life.

A third method of conservation is to provide such management as will assure the greatest social and economic good to the largest number of people in the long run. Called multiple-use, this socio-economic principle requires development, refinement, and application of many management techniques to the land, to every one of its resources, and to all the services that both may render to man. Above all, it requires plan-

[13] This section was adopted from material prepared by F. A. Silcox, Chief of Forest Service, United States Department of Agriculture.

ning and coordination of techniques, with vision and forethought for the needs of the future.

Invention of new socio-technical theories and practices has made possible the demonstration on the national forests of multiple-use land and resource management. Because of multiple-use of such land the net total yield of human, economic, social, and aesthetic values derived from a given land area exceed those obtainable from any customary single use. The resulting influence on living standards is definitely upward.

By means of these and other technologies the principle of multiple use may be extended to forest, range, and other wild lands generally, including in large measure such lands as are and may remain in private ownership.

Technologies of Producing, Managing, and Harvesting the Forest Crop

Four-fifths of our commercial forest land is in private ownership. It still furnishes 98 percent of all our forest products. With but minor exceptions, timber on it has been mined rather than cropped. For decades, fire protection was nonexistent or utterly inadequate. Immediate economic necessity, rather than scientific knowledge, still rules in the selection of species and trees cut. Through ignorance and economic pressures, little attempt has been made to leave the land productive. Forest operations have been transitory. Cut out, burn out, and get out has been the order of the day. Ghost towns, depressed agriculture, distressed social structures, have resulted. Now, when physical frontiers are gone, natural resources are limited, and many other conditions over the country have changed, these sores are difficult to heal. New ones cannot be tolerated, for the cumulative effect is very definitely felt on the social and economic structure of the Nation.

Technologies developed, refined, and applied by the Forest Service in connection with growing, harvesting, and managing the Federal forest crop, promise relief from the consequences of past practices on other wild lands. Included are technologies having to do with forest protection; silvicultural, nursery, and planting methods necessary to insure forest reproduction; selection and breeding of individual trees and tree species to increase future forest values; methods and machinery for harvesting rather than exploiting the forest crop; current forest inventories, and sustained-yield forest management.

Applied to a Great Plains area of some 70 million acres which includes more than 185,000 established farm units, some of these technologies will make of it a better place in which to live, will produce trees that grow faster, are less exacting as to soil and moisture, and will serve local needs to better advantage. And still wider application of all of them should make it possible to so manage our forest resources that—in part through a new type of forest community—it may in the future help to support with security and stability a greater share of the Nation's population.

Technologies of Forest Taxation

Reference has been made to the prominent part which private ownership must play in the development of sound forestry, and to the economic pressures which heretofore have tended to obstruct forestry and to promote destructive practices on privately owned lands. An element in these economic pressures is fear of burdensome and inappropriate taxation. Studies in forest taxation have developed a program which, if adopted by the States, will go far to remove this fear and to place forestry, so far as taxation is concerned, on a par with other forms of land use. The solution of the forest-tax problem will contribute substantially to bringing about better utilization of the forest resources which remain in private hands.

Technologies of Wood Utilization

During the past 20 years our per capita consumption of wood fell greatly, even in predepression years. Despite increases in population, so did total consumption. Investigations show that many former markets for wood have lately been unprofitable or unsatisfactory. Not because the material lacked intrinsic properties that were needed but partly because of improper preparation or unhandy forms for use, and faulty design of the commodity or the structure in which it was to be used.

Technologies with respect to wood utilization, evolved and adapted by the Forest Service point the way for wood and its products and byproducts to regain and broaden many old markets and capture new ones. Techniques in the pulp and paper industry include those having to do with utilization of new woods, modifications of mechanical and chemical pulping and bleaching processes, and application of them to woods that are cheaper and more plentiful than those heretofore used. In the construction industry are techniques having to do with usable strength data and grading rules for lumber and timber; use of chemicals to preserve wood and make it fire resistant; construction of large wooden members from small dimension stock; development of new structural units and systems adapted to large-scale production and rapid field assembly with low first cost, depreciation, and maintenance. In the chemical conversion field, technological developments include those to make wood plastic, bacterial fermentation of cellulose to acetic acid and isopropyl alcohol, and the production of wood gas and alcohols.

Application in industry and commerce of such technological developments presage things of wide

social import such as diversification of raw material for pulp, low-cost housing, and motor fuels that may successfully be used when gasoline becomes scarce or too high in price. They point to more complete utilization of wood waste (which has in the past reached 50–60 percent of the actual material grown or available on the stump), and added employment by the forest industries. They lead to conservation of our remaining forest resources.

Other Technologies Applicable to Wild-Land Resources and Services

(*a*) *To forage.*—Within the continental United States more than 334,000,000 acres of forest land are grazed by domestic livestock. In southern pine forests, forest forage is of distinct value to the rural population. In the humid East, grazing is usually detrimental to hardwood forests. In the West, where wild-land forage largely involves the national forests and the public domain, economic and social welfare is frequently dependent upon forest-land forage.

The American tendency to abuse and ruin grazing lands is historic. Overgrazing has been followed, all too often, by capture of soil by relatively worthless weeds, and erosion. This process has adversely affected enormous farm values, thus contributing to collapse of economic and social structures.

Technologies developed through research and applied administratively on the national forests, and other technologies now in process of development, promise to show the way to halting overgrazing and its inevitable consequences. Among these techniques are: Improved systems of grazing to bring about natural revegetation, obtain more stable forage production, and minimize livestock damage to timber production; development of methods and species for artificial reseeding of wild-land ranges and abandoned dry farms. Soil science, botany, range ecology, and the behavior of soils and plant and animal life under different methods of treatment are involved.

Combined into a socio-technical system of control, such techniques promise to bring huge benefits if they are extended to our seven hundred-odd million acres of range lands. For this resource might then contribute far more than it ever has done to the support of successful homes and prosperous communities.

(*b*) *To wildlife.*—A substantial part of the remaining wildlife in the United States, valuable for food, fur, and hunting, or for aesthetic purposes, finds its home on forest, range, and other wild lands. Wildlife directly interests more than 13,000,000 people who hunt and fish each year. It helps support many more and adds to the happiness of millions who are eager to catch a glimpse of wildlife in its home environments. This subject is dealt with in the section which follows, entitled "Technology and Wildlife."

What the Future Holds for Forestry

Primarily it holds an inescapable obligation to determine which lands of the Nation will render their highest and most permanent social and economic service through forest use, and to apply to such lands the best principles of management that can be evolved by human intelligence through the processes of science and research. It holds the need to substitute for crude processes of utilization new principles and methods through which the potentialities for human service, inherent in forests most completely, can be realized. It holds for the wood technologist, the chemist, and the silviculturist boundless opportunity for the development of new technologies contributing to human progress and welfare.

The potentialities of forests and their products have only partially and vaguely determined. Their latent values as sources of both mechanical and human energy largely remain to be developed. Under the skilled technical direction of the scientist they may be employed to supply a wide array of human needs in ways superior to those by which such needs now are met, and thereby develop a new outlet for labor. Wood as a source of mechanical energy has now passed beyond the field of experimentation. It is our greatest source of cellulose. Its preeminence as a source of numerous elements or substances basic to a wide array of useful commodities already is established.

Restoration of the United States to a condition of natural equilibrium is vital to its security and permanence. That requires the restoration of forests to much of the land from which they unwisely have been removed. To that end, ways must be devised whereby the products of forests may replace our nonrenewable natural resources. That is the field which lies ahead for the scientist and the technician.

XII. TECHNOLOGY AND WILDLIFE[14]

Few students of technology recognize the social importance of wildlife and the rapid strides which are being made in technologies affecting its preservation, development, and utilization. Publicly sponsored activity is increasing in research and management both in States and by the Federal Government. Wildlife is so closely associated with agriculture, with farms

[14] This section was prepared from information supplied by W. L. McAtee, Technical Adviser and Research Specialist, Bureau of Biological Survey, U. S. Department of Agriculture, and other sources.

and forests, that this technology deserves consideration with other fields more familiarly associated with the term "agricultural technology."

Because of long-continued and thoughtless exploitation, wildlife was greatly reduced. On areas where opportunities have been provided for demonstrating wildlife techniques, however, many striking instances of restoration have resulted.

Restoration has social significance not merely in satisfaction to sportsmen. It has meant a contribution to returning the balance of nature, to increasing the number of persons who depend upon wildlife, directly and indirectly, as a source of income; it has contributed to the food supply and to aesthetic satisfactions. Wildlife management is a field of knowledge and activity which promises to advance far in the next two generations.

Instances of restoration, reversing the trend of wildlife depletion, has been accomplished by development and application of techniques having to do with production and use of forage, as well as bio-ecological methods involving technical determination of food, feeding, and other wildlife habits.

Among techniques connected with wildlife generally those of classifying animals, working out influences of environment, and tracing their movements were prominent in early techniques of the Biological Survey and are still continued as basic research. Identification is the key to all that is known of relationships, distribution, and habits, and it enables the wildlife technician to shape his practice in the light of knowledge that all investigators, everywhere, have accumulated.

Millions of records from all sources have been assembled providing a satisfactory basis for generalizations in regard to the migration work. The technique of bird banding has been adopted, improved, and extended. Through it the movements of individual birds are traced, thus making possible more accurate definition of migration routes, general bird flyways, and winter and summer ranges. The scientific data bearing on the ranges and movements of birds are indispensable to proper conduct of wildlife management problems involving more than a single State. They have resulted in the annual promulgation of regulations protecting birds migrating between the United States and Canada, and the establishment of a system of migratory bird refuges giving adequate protection to wildfowl on the breeding and wintering grounds, and throughout the major flyways of the United States.

The technique of food habits research involves laboratory analyses of all sorts as well as field investigations of feeding habits and of the utilization of food supplies.

From the technique of research into their food habits have developed a number of other techniques for the improvement of environment, and for the encouragement of desirable and the control of undesirable species. Originally developed to throw light on economic values in relation to agriculture, horticulture, and forestry, this work soon responded to the needs of wildlife management.

Efforts to increase the more valuable kinds of wildlife developed in one direction into recommendations as to choice of kinds, care of propagating material, and as to where, when, and how to set out valuable wild-duck food plants. Plants affording refuge shelter and nesting cover were included and the technique became one of general improvement of the environment of wild fowl. These recommendations were acted upon extensively through a long series of years and resulted in great improvement of some properties (up to a tenfold increase by the financial scale), and are now serving as the basis of development and improvement of the vast new system of Federal migratory bird refuges (over 100 totaling more than 1,600,000 acres). Recommendations as to the value of marsh and aquatic plants and as to methods of propagating them have been of value also to muskrat farming.

XIII. THE DAIRY INDUSTRY[15]

Advances of the dairy industry result from efforts in three main directions: Improvement of quality of dairy products, efficient and economical production of milk, and the efficient distribution and consumption of milk and products manufactured mainly from milk. The last may include the development of new products as well as the extension of the use of those already developed. The aim in these fields of effort is to promote the use of greater quantities of dairy products. This can be accomplished most readily by decreasing the cost of milk products to consumers and by improving quality. For, although the nutritive and salutary advantages of milk and its derivatives in the diet are of great social importance, these reasons for increasing consumption are not so readily accepted by consumers as the most immediate and urgent arguments of greater saving of expense and of greater desirability of the product.

Decrease of retail prices cannot reasonably be made arbitrarily by cutting the dairy farmer's income, but must be brought about through greater efficiency and economy in production and distribution of dairy

[15] This section was prepared by E. O. Whittier, Senior Chemist, Bureau of Dairy Industry, U. S. Department of Agriculture.

products. Research and dissemination of the results of research are the means whereby quality improvement is being effected.

Breeding

Increase in our knowledge of the laws of breeding of dairy cattle and the wider dissemination of that knowledge are capable of increasing the average quantity of milk produced per cow, and of increasing the average quantity of fat per cow, not only through the increased quantity of milk, but possibly also through the increased percentage of fat. At present, fat is the most valuable constituent of milk from the dollar standpoint. It may seem to some observers that the possibility in maximum milk and fat yield per cow has advanced close to its limit, but much certainly remains to be done in carrying the available knowledge of better breeding to the dairy farmer and in inducing him to adopt its principles. As these principles are adopted, the overhead of labor and maintenance costs per unit of product decreases and a lowering of price to the consumer becomes possible.

Feeding

The cow is frequently spoken of as a machine for the conversion of feed into milk. The comparison is valid, not only for the function of the animal, but also for the relationship between the types of raw material fed and the quantity and quality of the finished product.

There is a tendency to change from the older rations of hay and grain for dairy cows to rations containing greater proportions of roughage—or even roughage alone—in the form of pasturage, well-cured hay, and silage. This change has recently been given impetus by methods of ensiling grasses, which contain no fermentable sugar, by the addition of molasses, whey, or other source of fermentable sugar or of mineral acid; and by a method of artificially drying of roughage so as to retain practically all of the nutritive constituents that were present in the green material.

Not only is there a direct economy in this scheme of feeding, but the quantity of vitamin A in the ration is thereby considerably augmented. Occasionally an extreme deficiency of vitamin A in the diet of the cow causes calves to be born blind or dead. Furthermore, the vitamin A supply of the cow is reflected in the vitamin A content of the cream and butter derived from the cow, which vitally affects human nutrition. This will be mentioned in that connection later.

The growing of more roughages and legumes, and of less grain, is of vital importance to the Nation in preventing soil erosion and in increasing and retaining soil fertility. Since from 70 to 90 percent of the grains grown are used for livestock feeding, an extension of the feeding of roughage would cause a redistribution of livestock farming. A smaller number of cattle would be kept in the vicinity of large cities, where large quantities of purchased feeds are fed, and those farmers who now specialize in raising grain would tend to raise livestock.

Experiments have shown that cows will produce about 70 percent as much milk on a ration consisting entirely of roughage of good quality as they will on a full-grain ration. Statistics indicate that the full-grain ration represents the average dairy feed of this country. If all our dairy cows were shifted from a full-grain ration to a roughage ration, it would take 50 percent more cows to produce the same quantity of milk as is produced at present.

The social change in many rural areas would be great, since the entire method of cropping would be changed. Instead of the routine of plowing, seeding, cultivating, and threshing each year, most of the land would be laid to perennial grasses and legumes that would be cut frequently at early stages of growth in order to obtain the maximum nutritive values. This frequent cutting would help in the control of weeds. Irrigation would become more common in those regions where necessary in order to maintain a more nearly constant rate of growth of herbage during the growing season. The appearance of the countryside would be vastly improved, since gullies, eroded areas, and weed patches would be largely eliminated and the fields would come to resemble lawns.

Delivery of Dairy Products

The question of changing methods and time of delivery of family milk supplies and the forms in which milk is offered becomes increasingly important socially. At present in most cities the milkman starts on his rounds at a very early hour in order that fresh milk and cream may be delivered in time for his customers' breakfasts. This schedule makes his life abnormal and irritates that great number of light sleepers. For each quart, or 2 pounds of milk on his truck, the milkman carries 2.6 pounds of bottle and bottle case, and for the smaller units of cream the proportion of dead load is still greater. Only between one-third and one-half the load on an outgoing truck consists of milk. The cost of such a method of retail delivery averages about 4 cents per quart. In summer, the milk is sometimes warm when the customer takes it into the house; in winter, it is frequently frozen. Overlapping of routes is a large question.

Researches in refrigeration, in container technology, and in the chemistry and bacteriology of dairy products have shown ways out of some of these awkward conditions. The greater refinements in sanitation on the farm and in the dairy, the development of more

effective refrigeration for the farm, for tank cars and trucks, for the dairy plant and for the home, and the attainment of greater speeds of transportation, have all contributed to make retail milk more palatable, much safer, and much less rapidly perishable than it was only a few years ago. It may now be kept for several days in the home refrigerator in excellent condition, instead of souring within a few hours. This points toward delivery of milk at times more convenient for both delivery man and customer. Daylight deliveries are already made in a few cities.

When the single-trip lightweight containers already in limited use in a few cities for milk sold from stores become somewhat less expensive and sufficiently durable to be used more than once, they will be used in retail deliveries. Other developments that tend to increase the salable proportion of the milk truck's load are the popularizing of milk powder and of frozen concentrated milk. Research will make it possible to accomplish sterilization with less or no cooked taste imparted to the milk. This will lead to greater use of evaporated milk in place of fresh milk.

Cheese

Cheese is a relatively neglected item of diet in the United States, the per-capita consumption in Europe being from two to three times greater than here. Consumption of large quantities of meat of itself need not affect cheese consumption unfavorably, for in England the consumption of both meat and cheese is high. Higher quality and somewhat lower prices appear to be the feasible means of increasing cheese consumption. Increased domestic production of high-grade cheeses of considerable variety should decrease prices noticeably. If part or all of the 60,000,000 pounds of relatively high-priced cheeses of foreign types now imported were manufactured in this country, the producer of cheese milk would benefit by higher milk prices, both because of the increased volume of milk required and because of the leveling-up effect of the greater market value of the foreign-type cheeses. Use of pasteurized milk in cheese making is likely to bring the South more extensively into this industry, thereby giving serious competition to the cheese makers of the northern-producing areas, such as Wisconsin, New York, and Ohio.

The development of domestic processed cheese and cheese spreads has definitely increased the domestic consumption of cheese. Each cheese can now be marketed economically in the warmer sections where formerly, because only large units were available, there was a large proportion of waste from drying and molding in retail stores. The current development of ripening and marketing Cheddar cheese in cans will stimulate cheese consumption, as will any other factor that improves the quality of cheese as received by consumers.

Previous to the World War, cottage cheese was made and used almost exclusively on the farms. As a result of efforts to popularize its wider use, it is being manufactured in city dairies from surplus milk and is used in ever-increasing quantities by our city population.

Butter

Within recent years there has been a marked increase in the popularity of sweet-cream butter. The slowly increasing manufacture of this butter has already had the effect in certain dairy areas of decreasing or abolishing the separation of cream on the farm and of requiring dairy transportation of greater frequency and greater volume.

A definite preference among consumers for a yellow butter has caused the rather general addition of artificial coloring matter, a practice that has legal protection. The recent discovery that the natural yellow color of butter is a good approximate index to its vitamin A potency seems to point logically to a reversed legislative attitude that will insist eventually on having artificially colored butter so marked on its container. The recent tendency for consumer preference for lighter-colored butter is likely to subside as the knowledge of the relationship between natural color and vitamin A potency becomes more widespread. This subject is highly important socially from the standpoint of public health.

Ice Cream

The development of the commercial ice-cream business to a position of importance in the United States has taken place mostly in the last 25 years. Production has more than tripled in that time. Within the last 5 years the increasing use of electric and gas refrigerators in the home and the greater availability of carbon-dioxide ice have shifted the place of consumption of much of the ice cream from the candy and drug stores to the home. Use of packages shaped to fit easily into the freezing compartments of refrigerators will probably accelerate this shift. The heralded use of the home refrigerator for the actual freezing of ice cream has not yet developed to appreciable extent, apparently because of the lack of a stirring device to whip in air and prevent formation of large ice crystals during freezing. Freezing units with agitators are now available for refrigerators, and ice-cream mix in milk bottles can be bought in some cities. Both developments aim to shift a portion of ice-cream making from the factory to the home, incidentally increasing the quantity of ice cream consumed.

Byproducts

One highly intriguing method of reducing the cost of dairy products to the consumer for the purpose of increasing consumption is that of shifting a portion of the total costs of production to valuable byproducts of skim milk and whey. Skim milk contains approximately 2.5 percent casein and nearly 5 percent milk sugar; whey contains 5 percent milk sugar, 0.75 percent protein, and 0.75 percent salts. About 40,000,000 pounds of casein are used industrially per year in this country, most of it in the paper industry. The recent commercial development in Italy of Lanital, a textile yarn from casein, is too new for valid predictions to be made of its effect on our dairy or textile industries.

The 5 percent of milk sugar in whey continues to be a problem in economic utilization. Though valuable nutritionally, it is expensive to isolate and refine in the small quantities at present in demand. As a raw material for fermentation to organic acids, milk sugar has possibilities that are already materializing in one plant built especially for carrying out the fermentation to lactic acid. It seems logical that dried whey should be used as food, since it consists chiefly of sugar, protein, and nutritionally valuable salts. It is now used to some extent in feeds for poultry and swine, such use nearly doubling the net income from whey over what would be realized from it without drying.

A beneficial effect on quality, and consequently consumption, of butter will result from the more extensive and profitable utilization of byproducts. The farmer, instead of delivering infrequently a comparatively low-grade hand-separated cream to the dairy, will deliver with greater frequency sweet whole milk, which, by factory handling, will yield a better grade cream and a higher score butter.

XIV. COTTON PICKERS[16]

No, you dare not make war on cotton. No power on earth dares to make war upon it. Cotton is king!

(Hon. J. H. Hammond, in a speech delivered before the United States Senate, March 4, 1858.)

Cotton, perhaps more than any other important crop, has resisted the general trend of technology in agriculture. There have been advances, of course, over the primitive methods employed a century ago, particularly in breaking the soil, distributing fertilizer where fertilizer is used, and in seeding and cultivating. But two of the major operations, chopping and picking, are still with but few exceptions performed by hand throughout the Cotton Belt.

The reasons, superficially, are obvious. First, the very nature of these operations—requiring, as they do, the exercise of a selective judgment not easily transferred to machinery—offers a considerable obstacle to mechanization. Second, labor throughout the South in normal times is plentiful and cheap—conditions which tend to be perpetuated by the cotton economy, and there is no great incentive to save labor time by transferring to machinery work otherwise performed by hand unless the labor saved, in terms of money costs, more than offsets the cost of the machinery.

In fairness to inventors, however, it cannot be said that they have not tried to solve the picking problem. For generations they have worked to transfer to tireless machines the work now performed by human hands. And although the picker has only recently come to wide public attention, the records of the United States Patent Office reveal a startling list of patents granted on cotton harvesting devices of varying description and merit. The first patent was issued in 1850. By 1864 there were 12. Since 1865, patents for pickers or other cotton harvesting devices, including strippers, have been granted every year except 1899, and the total number granted now exceeds 900. But even so, the cotton crop is still largely gathered by hand just as it was a hundred years ago.

Tempered by so long a record of costly experiment and failure, most people have grown callous to the ever-recurring rumor that a practicable mechanical cotton picker is at last a reality. Today the rumor is more persistent than ever before.[17]

Even though King Cotton be regarded as something of a despot, exultation at this prospect of emancipating millions of his subjects is not unmixed with grave skepticism and misgivings. There is skepticism because the tidings have often been shouted before, and found false; there are misgivings because, if they are not false, there is reason to cringe before the possible consequences. Reassurance is wanted that a machine capable of picking in 1 day as much cotton as an experienced hand can pick in a month will be a blessing, not a curse, to mankind. The legendary Frankenstein monster turned upon his inventors and destroyed them. The victims had failed to make adequate preparations for the control of their creation. It is not too early, therefore, to look into some of

[16] This section was prepared by Roman L. Horne, of the Agricultural Adjustment Administration.

[17] See Oliver Carlson, The Revolution in Cotton, The American Mercury 34 (134), 129–136, February 1935; Oliver Carlson, The South Faces Disaster, The American Mercury, 37 (145), 1–8, January 1936; William and Kathryn Cordell, The Cotton Picker—Friend or Frankenstein? Common Sense 5 (6), 18–21, June 1936; W. Carroll Munro, King Cotton's Stepchildren, Current History 44 (3), 66–70, June 1936; Victor Weybright, Two Men and Their Machine, Survey Graphic 25 (7), 432–433, July 1936.

the problems that would be raised if this dream of a century, a successful mechanical cotton picker should come true.

Cotton's Rise to World Power and Fame

Once before cotton was the spearhead of cataclysmic change—of the revolution which removed production for the market from the home to the factory and added an era to the economic organization of civilized man. It is more than idle fancy to suppose that cotton may again play a significant part in fundamental economic and social rearrangement.

Although cotton from planting to harvest has largely defied mechanization, cotton as a raw material in the fabrication of textiles played a dominant role a few generations ago in the series of convulsive changes—technological, economic, and social—known as the industrial revolution. A brief review of these changes will help to fix in better perspective the position and importance of the cotton crop in the United States today, and perhaps throw light on the possible effects of a mechanical picker.

Until the eighteenth century cotton was virtually a novelty even in England. It was a product of foreign soils, India and the West Indies, and as such was more amenable to technological change than were raw materials going into the long-established linen and woolen industries. From the invention of Kay's flying shuttle in 1733, which practically doubled the weaver's output of cloth, to the invention of Compton's "mule" in 1779, which increased the spinners' output of yarn a thousandfold, technological improvements went forward in every department of textile manufacture. Until the latter part of the eighteenth century both the loom and the spinning wheel, however, were still hand operated, with improvements first in weaving and then in spinning disturbing the balance of the production process. It remained for Dr. Edmund Cartwright, in 1785, to perfect the power loom which drove weaving from the family fireside to the site of power—first water and later steam—and paved the way for the modern factory system.

It must not be supposed, however, that modern industrial capitalism was ushered in without challenge. There was resistance then, as now, to machinery which saved a man's back at the expense of his job. John Kay, his home razed by disgruntled workers, was forced to flee the country. Hargreaves, the inventor of the spinning jenny (1770), fared badly at the hands of his neighbors and was forced to move to a distant village to carry on his work. Compton sought seclusion in an attic in a desperate attempt to foil a suspicious and threatening mob. But however distressing the temporary maladjustments which resulted from these advances in technology, the material well-being of the average man in the long run was immeasurably improved.

By 1790 the revolutionary advances in cotton textile manufacture had shifted the immediate emphasis from technology in fabrication to the more pressing problem of relieving the acute shortage in raw materials. In the United States cotton cultivation was restricted to the coastal plains of South Carolina and Georgia, where the entire crop for 1791 did not exceed 2,000,000 pounds, or about 4,000 bales, as contrasted with present production ranging from 12 to 15 million bales.[18] Failure of the South to exploit the possibilities of cotton growing prior to 1790 was due to the more profitable alternative uses to which the land could be put—so long as the lint had to be separated from the seed by hand. Meanwhile British textile manufacturers had to look to other countries where hand labor was cheaper for their supplies of raw cotton. This obstacle was removed once and for all by the invention of the cotton gin in 1793, an event of major importance in the birth of a new industrial order. Cotton culture spread north to the "frost line", and south and west under the banner of slave-holders prior to the Civil War. In 1790 there were only 677,897 slaves in the entire country. By 1860 there were 3,933,760 with only a few hundred scattered north of Mason and Dixon's line.

Meanwhile, advances in technology, both in agriculture and in manufacturing, led to a reduction in the proportion of income which the average man had to spend for food and textiles, thus leaving a larger proportion to be spent on other necessities and on luxuries.

The Cotton Belt

The Cotton Belt, extending south and west from the southeastern tip of Virginia, is one of the most highly specialized agricultural regions in the world. On the north the Cotton Belt is bounded by the "frost line", which dips irregularly southwest as it crosses the higher altitudes, marking the upper limit of the 200-day frost-free season, and an average summer temperature ranging around 77° F. On the south it is bounded by a subtropical border beginning in the Carolinas and following the coast line, taking in the greater part of Florida and extending west around the Gulf, where excessive rainfall in early autumn would interfere with the picking season. Approximately 1,600 miles long and from 125 to 500 miles in width, the Cotton Belt comprises about one-sixth of the area of continental United States. Here, on 3 percent

[18] M. B. Hammond, The Cotton Industry: An Essay in American Economic History. Part I. The Cotton Culture and the Cotton Trade. Publications of the American Economic Association, new series, no. I, p. 21, 1897.

of the earth's land surface, nearly 60 percent of the world's cotton was produced in the decade of the twenties. Seventy-five years ago, when Senator Hammond delivered his impassioned speech arraigning King Cotton against the world, the South was probably producing 90 percent of the world's cotton supply.

The population of the Cotton Belt proper in 1930 was approximately 21½ millions, one-half of which—or about 10¾ millions—was classed as belonging to the rural farm group. The other half was about equally divided between urban and nonfarm rural groups. Of the total, 30 percent, or about 6½ millions, are Negroes, more than half of whom live on farms. And while Negroes constitute only about 35 percent of the rural farm population for the Cotton Belt as a whole, in two States—South Carolina and Mississippi—Negroes on farms are slightly in excess of whites. At the western extremity of the Cotton Belt, however, Negroes constitute a very small minority of the total population. Although in the last decade there was a steady migration to the industrial North, the Negro, the mule, and the plow are still characteristic of the social and economic system which prevails in the greater part of the rural South.

The abolition of slavery first led to experiments in money-wage relationships between the plantation owner and the freed Negro. But the Negro's training generally had not made him a thrifty and long-calculating individual. He was inclined to work until he got paid, and then, regardless of the season, was likely to set forth to enjoy his new freedom until funds ran out. What was the meaning of freedom if he still had to work all the time? The landlord could get no satisfaction by suing for nonperformance of contracts.

A system evolved which gave the freedmen a sustained interest in the crop from beginning to end, and at the same time left active management in the hands of the landlord or his manager. The Negroes, for the most part, were penniless as well as illiterate and improvident, with limited opportunities for improvement. As they did not have the capital to set up as full-fledged tenants, they gradually dropped into one of the several stages of tenancy distinguished by the more or less complete dependency of the tenant upon the landlord not only for seed, livestock, and tools but also for the bare necessities of food, shelter, and clothing. As the decades rolled by the small one-mule farmer, whether white or Negro, frequently was forced to surrender his ownership status for something easier at the moment, but definitely lower in the social and economic scale. In 1880, for example, 38 percent of the farmers in Texas were tenants, as contrasted with 57 percent in 1935. In the same period tenancy in Mississippi increased from 44 to 70 percent, in Alabama from 47 to 64 percent.

According to the accompanying table, 58.4 percent of all farmers in the Cotton Belt are tenants. Of the total, whites outnumber Negroes by more than a quarter of a million, and the trend over the past decade has been toward an increase in the proportion of white to Negro tenancy.

Tenant farmers—Percentage of all farmers, 1880–1935 [1]

	United States	Cotton Belt		United States	Cotton Belt
1880	25.6	40.0	1930	42.4	61.3
1900	35.3	52.1	1935	42.1	58.4
1920	38.1	55.2			

[1] Adapted from the United States Census of Agriculture, 1935. States included in the Cotton Belt: North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, and Texas.

Meanwhile the center of the Cotton Belt has been shifting westward, approximately half the crop now being produced west of the Mississippi River where, especially in the uplands of Texas and Oklahoma, mechanization of cotton culture has already made considerable progress. The newer lands generally produce cotton at lower cost in terms of man- and horse-hours than that prevailing east of the Mississippi. Moreover, the larger farm units in the West make possible a more economical use of machinery and labor. For all farms reporting cotton in the four older cotton States of the Southeast—North Carolina, South Carolina, Georgia, and Alabama—only 9.3 acres on the average are devoted to cotton. In Arkansas, Oklahoma, and Texas, on the other hand, 22 acres of every farm on the average are devoted to cotton.

Mechanization of Cotton Culture

Suppose that a successful mechanical cotton picker—capable of picking five thousand pounds a day—is, or soon will be, a reality, and that it will be manufactured on a large scale and sold for approximately $1,000. What social and economic consequences might we expect?

Until mechanical cotton picking passes beyond the experimental stage limited progress can be made at mechanizing any preceding stage of the cotton crop. Tractors, gang-plows and other implements of modern agriculture have not played a more important role in the Cotton Belt because the labor of millions of workers—men, women, and children, white and Negro—is required for the picking season. Since the cheap labor is there, the cotton producer uses it as much as possible throughout the year rather than purchase expensive machinery. Furthermore, so long as a tractor, for example, cannot be used in the picking season, none

but the larger operators can afford to own one merely for turning the soil. The advent of a mechanical cotton picker, assuming its ready adoption, would make the tractor practically indispensable in the picking season. Thus the tractor's availability would be an incentive for substituting its use for that of horsepower in preparing the land for planting in the spring. It is probable that "chopping" could be further mechanized if that operation were the last requiring a considerable amount of hand labor. There are 8 to 9 million individuals in nearly 2 million tenant families in the 10 Cotton States. If mechanization proceeded rapidly without substantial change in the present cotton acreage, it has been estimated that at least one-fourth of these tenant families to three-fourths of these would no longer be needed. But any such estimate is likely to be unrealistic until the rate at which mechanization would proceed can be forecast—and this in turn awaits proof that the picker is practical and that it can be produced at low cost.

If, on the other hand, lower cost of production leads to increased consumption of cotton both at home and abroad, acreage will be expanded and many who would otherwise be unemployed will find work not only in the cotton fields but throughout the agencies engaged in handling and processing cotton. Moreover, further reduction in the cost of textiles will tend to expand consumer demands in other directions and, in turn, provide more jobs. Lower production costs offer some, but limited, assurance that we shall recapture the foreign markets once dominated by American cotton, because the same machinery would be available to other cotton-growing countries. India, Brazil, China, Argentina, and Russia are also important cotton-producing countries.

Although mechanization of cotton culture would undoubtedly hit the tenant and "cropper" farmers hardest, it would also intensify the struggle of the small farmer-owner who, with family labor, one or two mules, and rather primitive implements, has long struggled for a bare subsistence—often against harsh terms for credit both for fertilizer at the nearest village and for provisions at the crossroads store. He will be unable to buy a mechanical cotton picker and a tractor, and even if he could, its use would be uneconomical on small acreage. When cotton is 10 to 12 cents a pound the average small farmer little more than breaks even.[19] If with the introduction of a mechanical picker cotton can be produced profitably at a lower price on the larger farms, the small farmer may be overwhelmed by competition unless hand-picked cotton, because of its freedom from trash, discoloration, and roping, comes to command a material premium over machine-picked cotton.

In a restricted section of Texas an improved substitute for hand labor in picking has been in use for more than a decade. A sled or "stripper" is dragged along the rows gathering both the open and unopened bolls. In sections where this device is used, however, a large percentage of the bolls ripen at the same time. A study made a few years ago reveals that even by this crude method of gathering cotton one man with two horses and a "sled" can harvest about 4½ acres, or a little less than two bales a day at an operating cost of about $3 a bale on the basis of current dollar values, as contrasted with the cost of hand-picking ranging from $12 to $15 a bale.[20] There is, of course, a certain amount of foreign matter gathered which both increases the cost of ginning and lowers the quality of the fiber. This method of gathering the cotton crop in areas where it can be applied reduces by about three-fourths the man-hours required in picking, and, consequently the family size cotton farm can be increased in about the same proportion.[21]

Cotton Pickers

Exhibitions and tests in 1936 of cotton pickers in Texas and Mississippi have led many people to believe that the key to complete mechanization of the cotton industry is closer to a reality today than ever before. It will require several years thoroughly to test the machines on different soils, topography and varieties of cotton. But if the confidence of the inventors is justified, the picker will inevitably create new social and economic problems.

In the hundred and forty years since Eli Whitney patented the gin, millions of dollars have been spent and the inventive genius of thousands of men has been concentrated upon this search for a mechanical substitute for human fingers. If this substitute has now been found, it will deserve a place high among the inventions and discoveries which have profoundly affected the social and economic arrangements of mankind.

Pulled by a tractor, the newer type of cotton pickers straddles the row of cotton thrusting hundreds of spindles into the open bolls. The cotton, along with a considerable amount of trash, is wound about the spindles, removed mechanically, and conveyed to a container on the machine.

In exhibition tests one of these pickers is reported to have picked as much as 5,000 pounds of seed cotton

[19] In 1929 the gross farm income per farm from all sources averaged $1,571 for the 10 cotton States, and in 1934, $669. At the same time, the gross farm income for the remainder of the United States averaged $2,414 and $1,353, respectively.

[20] L. P. Gabbard and F. R. Jones, Large-Scale Cotton Production in Texas. Texas Agricultural Experiment Station bull. 362. 1927. 24 pp.

[21] Mechanization of Agriculture as a Factor in Labor Displacement, Monthly Labor Review 33 (4) : 749–783. October 1931.

a day, as contrasted to 125 to 150 pounds a day for the average hand picker. Until more machines are produced and more intensive studies are completed, the cost of picking a bale of cotton with the mechanical picker must remain in doubt. It is worth pointing out, however, that many cost items are involved, such as depreciation, interest on investment, normal repairs, taxes, housing, and insurance, all of which might be classed as overhead expenses. In addition, there are such direct operating expenses as operators' wages, tractor cost, value of cotton lint and seed left in the field, and the loss in value from lowered quality. It is the total of all these items in comparison with the cost of hand picking which will largely determine the final economic feasibility of the mechanical cotton picker. For the moment, however, we are concerned only with the possible effects of a successful picker, if and when introduced.

If we assume that cotton acreage will remain about the same, and that a successful machine will be produced in large quantities and sold to all who can afford to buy, tenant farming as it now exists in the South would undergo change. Some tenants and sharecroppers would still be needed as laborers in the cotton fields, but many would have to turn elsewhere for a livelihood.

Would they pour into the North and seek employment in industry? If so, what would be the effect on organized labor, wages, and standards of living among both skilled and unskilled workers? Many of the people from the rural South have had almost no experience with industrial discipline and complicated machinery; could they be trained to useful and self-supporting employment?

On the farms of the 10 cotton States are to be found 70 percent of all mules and 16 percent of all horses on farms in the United States. These 5,000,000 horses and mules, upward of 30 percent of the total number of horses and mules on farms in the United States, together consume annually the produce from approximately 25,000,000 acres of farm land. Will the cotton picker, necessitating the use of a tractor, force the elimination of a large percentage of these horses and mules, along with the hoe, the one-horse plow, and the great hordes of roving cotton pickers? If so, smaller acreage will be required to feed the working stock of the Nation.

The good and the bad effects of such a machine are not clearly and distinctly set apart. The cotton picker would cut down sharply the greatest single source of employment for woman and child labor in America. They could not compete with a successful mechanical cotton picker, especially in the river bottom areas of Mississippi and Arkansas, and in the Gulf coast prairie

FIGURE 19. Hand picking is slow and laborious.

and the Texas black prairie, where high acre yields and large plantations would probably encourage the adoption of new mechanical equipment. Their backs and their hands would be spared the labor. But how else, it may be asked, are these people to make a living? Would a larger percentage of them be driven into domestic service? Or might the mechanical picker result in employment of fewer members of a family, but these at better wages, thus releasing women and children for other tasks which might contribute to higher educational and living standards? This latter course is not improbable in view of the experience with advances in machinery in other agricultural pursuits.

These effects are based upon the supposition that the cotton picker will be rapidly introduced, privately purchased, and employed just as any other piece of capital equipment is purchased and employed. Perhaps arrangements can be invented which will help to distribute widely the profits derived from conserving human labor. Many questions which arise may never have to be answered if, as in the case of many improvements, the cotton picker requires decades rather than just a few years to get into common use. Given a long period of introduction the period for readjustment would be longer and individuals actually displaced by this labor-saving device might be absorbed elsewhere with only limited shock. The key to

FIGURE 20. Mechanical picking (with an experimental machine).

the degree of disturbance which the cotton picker will create, therefore, to a large extent lies in the length of the period of introduction.

Does the solution lie in whole or in part in the development of farm cooperatives, or more diversified farming? Will northern industry move into the South and take up the slack in the labor supply? Perhaps new industries will grow out of the small beginnings that have been made in air conditioning, large-scale production of prefabricated houses, and rural electrification—to the benefit of all parts of the country. A cotton picker would prove advantageous if, as millions were released from the cotton fields, new industries surged forward to employ idle hands.

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